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Impairment of Executive Cognitive Control in Type 2 Diabetes, and its Effects on Health-Related Behavior and Use of Health Services

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Abstract

We evaluated whether, among persons with type 2 diabetes: 1) impaired executive cognitive functioning (ECF) is more common than among people without diabetes; 2) ECF is associated with the capacity to engage in instrumental health-related behaviors; and 3) worse ECF is associated with increased health services utilization. A population-based sample of 1,063 older people was interviewed regarding medical history and health services utilization; participants were administered the Mini Mental State Exam and the Behavioral Dyscontrol Scale, a measure of ECF. Participants with diabetes performed more poorly on cognitive measures than those without diabetes. Among those with diabetes, lower ECF was associated with more outpatient care and with ever having been in a nursing home. Impaired behavioral self-regulation may affect the capacity to engage in behaviors that could improve clinical status, resulting in greater health services use. The findings suggest the possibility of a positive feedback loop, with ECF deficits adversely affecting adherence, in turn leading to greater cognitive impairment—an issue for future research.

Keywords

Diabetes Mellitus; Complications of Diabetes Mellitus; Cognition Disorders; Executive Functioning; Health Behavior; Health Services Use; Patient Compliance; Behavioral Dyscontrol Scale; San Luis Valley Health and Aging Study

Type 2 diabetes mellitus (DM) is associated with impaired cognition (McGuire, Ford, & Ajani, 2006; Sinclair, Girling, & Bayer, 2000). When DM is untreated or inadequately

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managed, there may be significant complications, and the costs of treatment may be quite high. In this paper we address three interrelated issues: 1) the relationship between diabetes and executive cognitive functioning (ECF); 2) the relationship between ECF and processes of diabetes self-care; and 3) the relationship between ECF and health services utilization among diabetic persons.

The prevalence of cognitive impairment among people with diabetes has been well documented. For example, some reports have noted a link between diabetes and both vascular dementia and Alzheimer's disease (AD; Bruce, Harrington, Davis, & Davis, 2001; Stewart & Liolitsa, 1999), possibly in conjunction with an increase in the prevalence of cerebrovascular disease (CVD) among diabetic persons. However, this excess risk of AD remains significant even after adjusting for CVD (Ott et al., 1999). In addition to a possible relationship between diabetes and frank dementia, longer duration of diabetes is associated with less severe yet clinically significant cognitive decline (Umegaki, 2010). It appears that inadequately controlled type 2 diabetes may affect verbal learning and memory, attention and concentration, ECF, and mental status (Asimakopoulou, Hampson, & Morrish, 2002; Cosway et al., 2001; Fontbonne et al., 2001).

Aging is accompanied by an increased prevalence of cognitive impairment, reflecting not only neurodegenerative disorders such as AD, but also the effects of chronic illness, medications, and the aging process itself. The incidence and prevalence of type 2 DM have increased in recent years, with a decreasing age of onset, and it is likely that DM is becoming an important cause of cognitive deficits among older people. Both hyperglycemia and hypoglycemia may affect cognition directly (e.g., Punthakee et al., 2012), but impaired cognitive abilities also may be affected by other conditions associated with diabetes, including hypertension, hyperlipidemia, inflammation, and microvascular disease (Bruce et al., 2001).

The clinical significance of cognitive impairment as a complication of diabetes has been under-appreciated. This is problematic insofar as comorbid cognitive disorders are likely to complicate diabetes self-care, even among those for whom such impairment is mild (Park & Jones, 1996; Sinclair et al., 2000). Older people with type 2 DM are likely to have difficulty in learning about their disease and its treatment, and when ECF is deficient they may have trouble using knowledge to guide their behavior in the service of managing their health and attaining favorable metabolic outcomes (Park et al., 1992; Persell et al., 2004).

ECF is central to the capacity to use intentions to engage in purposeful activity. Hence, it involves planning, considering the possible consequences of a course of action, initiating activity intended to attain one's goal, inhibiting activity inimical to attainment of a goal, accurate monitoring of one's behavior and its effectiveness, and adjusting one's activity as needed should it appear to be ineffective (Fuster, 2000; Grigsby & Hartlaub, 1994; Grigsby et al., 1998).

Executive functioning is a prerequisite for the ability to engage actively with daily life, to make an effective and sustained effort at tasks that may be novel or difficult, and to initiate and carry out goal-directed behavior. Overriding habit, and establishing new and adaptive

behaviors, involves the deliberate conscious control of purposeful activity, which is the essence of ECF (Fuster, 2000). Behavior related to health and disease management (e.g., self-monitoring of blood glucose [SMBG]; changes in diet and physical activity) is difficult to change because it is largely habitual. Habits are enacted automatically and nonconsciously, and going against the grain of habit is difficult, requiring sustained effort (i.e., ECF) to monitor and abandon existing habits, and to acquire new ones.

Although a number of factors may influence diabetes self-care and outcomes, including one's knowledge of the disease (Persell et al., 2004), self-efficacy (Sarkar, Fisher, & Schillinger, 2006), food security (Cuesta-Briand, Saggars, & McManus, 2011), and depression (Parada et al., 2006), we were concerned in particular with the influence of ECF. Effective self-management of DM requires a relatively complex behavioral regimen, frequently involving significant lifestyle modifications. Certain habitual behavior must be inhibited (e.g., dietary indiscretion), and new habits acquired (e.g., glucose monitoring, medications, exercise). This demands adequate executive ability. However, approximately one-third of community-dwelling persons age 60 may have mildly to severely impaired ECF (Grigsby et al., 2002), and incident diabetes among these individuals may present serious challenges to self-management. Moreover, these cognitive problems could be exacerbated by the effects of diabetes. Because persons with poor ECF are limited in their ability to engage autonomously in goal-directed activity, they may require adjustment of the usual approach to care (Park & Jones, 1996; Park et al., 1992).

It seems probable that inadequate diabetes self-management associated with cognitive decline may further impair cognition, leading to greater difficulty with self-care, and increased costs of treatment. A positive feedback pattern of this sort may be especially pronounced among individuals with greater ECF deficits.

We tested three related hypotheses within a single epidemiologic study: 1) older people with type 2 diabetes will show greater cognitive impairment (especially ECF) than will persons without diabetes; 2) among older persons with type 2 diabetes, deficits in ECF will be associated with an impaired capacity for management of medications and meal preparation, greater likelihood of smoking, and inadequate dental hygiene; and 3) among older persons with type 2 diabetes, deficits in ECF will be associated with greater self-reported use of outpatient, emergency, and inpatient health services.

Methods

Sample

The San Luis Valley Health and Aging Study (SLVHAS) is a population-based epidemiologic study of chronic illness and disability among rural Hispanic and non-Hispanic white (NHW) persons, aged 60 years and older, who live in two rural counties in southern Colorado (Hamman et al., 1999). In 1992 and 1993, all occupied households in both counties were identified and enumerated, with an overall 97.2% response rate. To be eligible for participation in the SLVHAS, residents of Alamosa and Conejos counties had to be 60 years of age and of either Hispanic or NHW ethnicity. Differential sampling was used within age and ethnic strata in order to maximize participation of Hispanic individuals. All eligible

Hispanics over the age of 64 were invited to participate, as were 49 percent of Hispanics between the ages of 60 and 64 years. Among NHWs, we sampled 37 percent of those between 60 and 64 years, 58.5 percent of those between 65 and 79 years, and all eligible persons aged 80 years and older. Although 1,982 community-dwelling people were invited to participate, 168 (8.4%) died before an interview could be completed, 125 (6.3%) moved out of the study area, and 14 (0.7%) were ineligible because of inaccurate information regarding age or ethnicity. Three hundred seventeen persons (16.0%) refused to participate, leaving a total of 1,358 individuals who completed a baseline interview (68.5% of the initial total, and 81.1% of eligible, surviving residents). Participants were interviewed a second time after a mean interval of 22 months, and we now report our analysis of data obtained from individuals seen at both baseline and follow-up.

Of 1,358 community-dwelling participants interviewed at baseline, 1,157 (85.2%) completed a follow-up visit. Among non-responders were 105 deceased participants (7.7%) and 96 (7.1%) who withdrew from the study. Of the remainder, 116 (8.5%) required proxy respondents. Participants with incomplete data were excluded from analyses, leaving a sample of 1,063 (78.3%). Of these, 252 persons informed the interviewer that they had been diagnosed as having diabetes (23.7%).

Data Collection

Participants were interviewed in their homes by interviewers who were bilingual residents of the San Luis Valley. Participants were given the option of being interviewed in Spanish, but only 5.5% of Hispanics requested interviews exclusively in Spanish. Among bilingual persons, interviews often were conducted both in Spanish and English.

Measures of Cognition

We used five measures of cognition, assessing executive functioning (behavioral and attentional self-regulation), working memory, procedural learning, general mental status, and constructional praxis (in this case, the ability to copy geometric designs). We expected deficits in the first three of these, but not in general mental status or constructional praxis (both of which are commonly affected by Alzheimer's disease and focal vascular lesions). The total scores for the Behavioral Dyscontrol Scale (BDS) and the Mini Mental State Exam (MMSE) were used, as were two items from the BDS and one from the MMSE, as these items represent aspects of cognition that are of interest, but that are subsumed under the total scores for the two tests. The BDS is a 9-item behavioral scale measuring the capacity for autonomous regulation of behavior and attention. The instrument has high internal consistency (Cronbach's $\alpha = 0.87$), and excellent interrater (ICC $> .95$) and retest (0.89 to 0.93) reliability (Grigsby, Kaye, & Robbins, 1992). The ICC for the two items was > 0.95 (Grigsby et al., 1992). The version of BDS scoring used in this study has a range from 0–19, with impairment defined as any score of 14 or lower (approximately 2 or more standard deviations below the mean for adults younger than 60).

We also used the scores obtained on two BDS items. The first is a test of procedural learning in which participants are asked to learn a sequence of three hand positions, performed as rapidly as possible (fist-edge-palm; Luria, 1980). The second involves alternate counting

and recitation of the alphabet (1-A-2-B...11-L-12-M; Grigsby, Kaye, & Busenbark, 1994); this item is sensitive to problems with working memory and attentional control. We used the total BDS score as a measure of ECF, and the two individual items as measures of procedural learning and working memory.

The Mini Mental State Exam (MMSE) (Folstein, Folstein, & McHugh, 1975), a brief measure of general mental status, is a 30-point scale with acceptable internal consistency ($\alpha = 0.61$; Costa et al., 2012), retest, and interrater reliability, frequently used with older people. We used the total MMSE score (range = 0–30), as well as an item requiring the participant to copy a drawing of two intersecting pentagons (constructional praxis).

The Center for Epidemiologic Studies Depression scale (CES-D; Radloff, 1977) was used to assess depression, which was used as a covariate. The CES-D has internal consistency of 0.85 and higher. Retest reliability is somewhat lower (it has been estimated at 0.51 to 0.67; Radloff, 1977), as might be expected of a measure of affective state.

Measures of Functional Status

Among health behavior items relevant to diabetes in the SLVHAS, participants were asked about their frequency of oral hygiene (flossing and brushing), both of which are important because of the increased risk of periodontal disease and related disorders associated with DM. Participants also were asked whether they had any limitations of ADL/IADL functioning (Center for the Study of Aging and Human Development, 1978), and were administered a measure of observed, simulated ADLs/IADLs (Mahurin, DeBettignies, & Pirozzolo, 1991).

On the self-report measure of ADLs and IADLs (Center for the Study of Aging and Human Development, 1978), a response indicating difficulty with any IADL task was given a score of 1, while a response indicating no difficulty was scored 0. In addition to *yes* and *no* responses, it was possible to respond “doesn’t do for other reasons.” These responses were recoded as indicating that the individual had no difficulty with the specified task. The number of items on which difficulty was reported was added to create a summary score for IADLs (range = 0–8). This summary score was used in the analysis, as were individual items assessing medication management, meal preparation, and the two items on frequency of dental hygiene.

Participants also were administered an abbreviation of the Structured Assessment of Independent Living Skills (SAILS), a behavioral measure of the performance of a number of simulated ADLs and IADLs (Mahurin et al., 1991). The original SAILS consists of 50 tasks across 10 functional areas: fine motor skills, gross motor skills, dressing, eating, expressive language, receptive language, time and orientation, money-related skills, instrumental activities, and social interaction. In the present study, participants were evaluated on the total IADL score, and on medication management (viz., tasks assessing their ability to understand medication labels, open a pill bottle, and handle medication). Higher scores on the SAILS indicate better functioning.

The seven dependent measures used in this study included oral hygiene (frequency of brushing and frequency of flossing), self-reported IADLs (total IADLs, medication management, and meal planning), total IADL difficulties on the SAILS, and SAILS medication management.

Weight

All participants were weighed to the nearest 10th of a pound with shoes removed, wearing light clothing. In the interview, they were asked whether their weight had changed in the previous six months. If they answered *yes*, they were asked how many pounds they had gained or lost, and whether the gain/loss was deliberate.

Measures of Health Care Use

Health care utilization among participants with diabetes was measured by self-report in response to 10 questions. Participants were asked: 1) if they had *ever* spent time in a nursing home, and 2) if they had been admitted as an inpatient in the previous 12 months. They then were asked questions about each of the following *for the previous 12 months*: 3) whether they had any episodes of inpatient care; 4) number of inpatient admissions; 5) length of stay (LOS) in hospital; 6) number of nursing home admissions; 7) number of episodes of home health care; 8) number of days of home health care; 9) number of outpatient, clinic, and emergency room visits. Finally, participants were asked: 10) the number of outpatient, clinic, and emergency visits in the previous two weeks.

Statistical Analysis

To assess the hypothesized relationships among diabetes, cognition, health-related behaviors, and health services utilization, we computed linear and logistic regression models using PASW (SPSS) Statistics, version 17. In tests of hypothesis 1, concerning the relationship between diabetes and cognition, the entire sample of 1,063 diabetic and non-diabetic patients was used in five regression models. For tests of hypotheses 2 and 3, which examined the relationship between health behaviors and health care use, analyses were limited to the subsample of persons with a diagnosis of diabetes ($n = 252$). In the case of dichotomous dependent variables, binary logistic regression models were used. Continuous/interval dependent variables were analyzed using ordinary least squares regression. Analyses for all three hypotheses were hierarchical, adjusted first for age, education, ethnicity, and gender. For hypotheses 2 and 3, in a second block we controlled for burden of self-reported comorbid conditions. Comorbidity was measured by the total count of physician-diagnosed major chronic diseases (excluding diabetes) including cancer, heart attack, transient ischemic attack, major stroke, angina, Parkinson's disease, high blood pressure, heart failure, emphysema, chronic bronchitis, chronic obstructive pulmonary disease, cirrhosis, kidney failure, osteoporosis, seizure disorder, migraines, depression, heart or blood vessel surgery, and angioplasty. To control for depression, we entered CES-D score in a third block, following comorbidity. To control for multiple comparisons, we adjusted α -values using the False Discovery Rate (FDR; Benjamini & Hochberg, 1995). The results of individual regression analyses are shown in Tables 1 and 2.

Results

Characteristics of the Sample

The sample ($n = 1,063$) was 58.1% female and 51.8% Hispanic. The mean [SD] age was 72.8 years [7.15], and mean [SD] education was 10.9 years [3.49]. The mean [SD] number of comorbid diagnoses was 2.1 [1.68]. The diabetic subsample ($n = 252$), for which we analyzed data concerning hypotheses 2 and 3, was 58.7% female and 63.9% Hispanic. Mean [SD] age was 71.8 years [6.67], and mean [SD] education was 10.3 years [3.46]. Mean number of comorbid diagnoses, excluding diabetes, was 2.04 [1.58].

Cognition and Diabetes (Hypothesis 1)

We compared persons with and without diabetes using hierarchical linear regression models, adjusting for age, education, gender, and ethnicity in the first block, followed by diagnosis of diabetes (yes-no). Dependent (cognitive) variables included total BDS and MMSE scores, and the items assessing motor procedural learning, working memory, and constructional praxis. People with diabetes scored more poorly than those without diabetes on the BDS ($p < 0.05$), MMSE ($p < 0.05$), alphanumeric sequencing (working memory, $p < 0.05$), procedural learning ($p < 0.01$), and copying intersecting pentagons (constructional praxis, $p < 0.001$). In a model predicting BDS score, more education, younger age, and NHW ethnicity were positively and significantly associated with ECF (all $p < 0.001$). Neither gender nor comorbidity made a significant unique contribution to the variance. The results are summarized in Table 1.

Cognition and Health Behaviors (Hypothesis 2)

Regression models were computed for the seven health behavior variables for all individuals with diabetes (Table 2). In adjusted models controlling for age, sex, ethnicity, education, comorbidity, and depression, the MMSE and BDS were assessed separately as correlates of health-related behavior. ECF was a significant predictor, in the expected direction, of the five IADL variables (p values from < 0.013 to < 0.001), but it was not significantly associated with either dental hygiene variable. The MMSE was a significant predictor only of toothbrushing ($p < 0.05$) and total IADL performance on the SAILS ($p < 0.01$). Too few participants had gained weight in the prior six months to permit analysis of this outcome.

Cognition and Health Services Utilization (Hypothesis 3)

For individuals with diabetes ($n = 252$), risk-adjusted linear or logistic regression models were computed for all 10 health services utilization variables (Table 2). None of the relationships between general mental status (MMSE) and these measures was significant. However, ECF was a significant predictor of the number of nursing home admissions in the past 12 months ($p = 0.008$), and of the number of clinic and emergency room visits in the previous 12 months ($p = 0.004$). The association between ECF and any nursing home admissions in 12 months, and between ECF and the most recent nursing home length of stay fell just short of significance ($p = 0.077$ and 0.078). For neither of the inpatient care variables (admissions and length of stay) was mental status or ECF a significant predictor.

Discussion

The results provide support for all three hypotheses. First, in demographically-adjusted analyses, people with diabetes performed more poorly than non-diabetic persons on all five cognitive variables (mental status, ECF, working memory, procedural learning, constructional praxis). The other hypotheses were tested using only the subsample of persons with a diagnosis of diabetes. Among people with DM, the second hypothesis (association between cognition and health behaviors) also received support. In models controlling for comorbidity, ECF was associated with all IADL variables, higher BDS scores predicting better functioning. The MMSE was associated with frequency of toothbrushing and total IADLs on the SAILS. For the third hypothesis, which addressed the relationship between cognition and health services utilization, mental status (MMSE) was not associated with any dependent variables. Executive functioning, however, was associated with having been a resident in a nursing home in the past 12 months, and with the number of outpatient clinic and emergency room visits in the previous 12 months. The number of nights in a nursing home fell just short of significance ($p = 0.078$). Neither hospital admissions nor length of stay were significantly associated with any cognitive variable.

Diabetes and Cognition

The findings demonstrate an association between diabetes and cognition, a result consistent with previous work (Asimakopoulou et al., 2002; Cosway et al., 2001; Fontbonne et al., 2001). While we were especially interested in ECF, we anticipated differences between people with and without diabetes on measures of ECF as well as working memory (which is closely related to executive functioning). We also expected to find deficits in procedural learning, but not on overall mental status or constructional praxis. Contrary to our predictions, performance on all these measures was worse among individuals with diabetes than among those without. Interestingly, constructional praxis is likely to be impaired primarily in association with focal neurologic lesions (as a result of stroke, for example) or with certain types of dementia (e.g., Alzheimer Disease). We did not expect to find constructional dyspraxia in this study, anticipating instead that diabetes would be associated primarily with problems in a constellation of cognitive deficits involving working memory, ECF, and information processing. Deficits in these abilities are frequently non-specific in etiology, and are commonly observed following a variety of neurologic and systemic insults. Although the pathologic basis of the primary cognitive deficits in DM is not clearly understood, one possibility is that small vessel ischemic disease associated with Type 2 DM may affect cognition among older persons with diabetes. In this regard, previous research provides strong evidence that white matter disease impairs ECF irrespective of its location (Murray et al., 2005; Tullberg et al., 2004).

Diabetes, Cognition, and Health-Related Behavior

Among diabetic participants in the SLVHAS, impaired ECF was associated with a decreased ability to engage in certain health-related behaviors. This is consistent with research in other populations (Brega et al., 2008; Grigsby et al., 1998; Park & Jones, 1996), and is important because a fundamental aspect of ECF is the capacity for behavioral control and inhibition.

An individual with diabetes must make many decisions on a daily basis about behaviors that influence his or her condition, including choices regarding diet, exercise, tobacco use, and SMBG (American Diabetes Association, 2011). ECF is an important determinant of the quality of those decisions, and of the individual's ability to put them into action.

Problems with IADL performance were associated with deficient ECF, for both self-reported and observed tasks (all $p = 0.001$ to 0.012). The relationship between medication management and ECF was of particular interest in this context, as it has clear implications for the reliable use of insulin and other medications. The link between ECF and health behavior is supported by previous findings showing that among the community-dwelling participants in the SLVHAS, there was a relationship between successful smoking cessation and ECF (Brega et al., 2008). That finding was noted for smokers in the entire SLVHAS sample, but the present subsample of smokers with diabetes too small for replication of that result (there were only 40 current smokers with diabetes), and this relationship was not tested. Similarly, too few people with diabetes had gained unwanted weight over the previous six months to allow meaningful analysis of weight control.

Diabetes, Cognition, and Health Services Utilization

Finally, ECF, but not general mental status, was associated with the utilization of health services. Other research has demonstrated that the association between diabetes and cognitive decline was substantially larger among persons who reported fewer physician visits within the past 6 months (Crowe et al., 2010). In that study, decreased access to healthcare may have been associated with poorer health outcomes, with a consequent decline in cognition. This relationship is likely to be complex and bi-directional, however, as our data suggest that cognitive impairment among diabetic persons could itself be associated with an increase in the utilization of certain health services when they are available. In the SLVHAS, this was observed for both outpatient and emergency visits, as well as nursing home admissions. Hence, deterioration of executive cognitive control, with its associated impairment of behavioral self-regulation, likely leads to a decline in the capacity for self-care. It also may be associated with failure to seek professional care in a timely manner, thereby necessitating more of certain types of health services.

Although this study cannot demonstrate causation, we suggest that the findings are consistent with the following readily testable model. As ECF becomes impaired, it may become increasingly difficult for a diabetic individual to make the effort required to adhere to medical guidelines for self-management of his or her metabolic disease. Lifestyle changes cannot be easily accomplished and maintained, nor can diabetes education produce the kinds of behavioral alterations that are required. People with type 2 DM who demonstrate ECF deficits may have every intention of following lifestyle recommendations (e.g., smoking cessation, exercise, medications), but because of deficiencies in behavioral self-regulation, they are likely to be unable to act upon the recommended guidelines. The consequent failure to adhere to medical protocol could result in worsened health status, and in an increased need for certain health services. Moreover, deficient planning and increasing behavioral disorganization may predispose such persons to delay medical treatment until they need

emergency care. They also may be more prone to engage in inappropriate utilization of emergency facilities for routine care.

An important finding of this study was that procedural learning was impaired in people with diabetes. The procedural learning system is required for acquisition of, and change in, habitual behavior, skills, and other behavioral processes. If one wishes to disrupt maladaptive habits and to acquire new and more constructive habitual behaviors, both ECF and procedural learning must be intact. ECF permits one to make deliberate, conscious effort, and procedural learning is necessary to make new behaviors automatic and nonconscious (i.e., habitual). The results of this study suggest that both these functional systems may be deficient among people with DM.

Conclusion

The development and progression of Type 2 diabetes is known to be associated with maladaptive habitual lifestyle behaviors. Although diabetes can be managed effectively by adherence to self-management guidelines (Inzucchi et al., 2012), its persistence may lead to impaired executive functioning, working memory, and procedural learning (all of which we found to be impaired in association with diabetes). Health education alone will not change behavior (Schroeder, 2007; Seldin, 1981), and the presence of these specific cognitive deficits makes it increasingly difficult to break old habits and to acquire new health-related behaviors—a process that depends on executive functioning to deliberately disrupt habitual behavior, and on procedural learning to acquire new habits (Park & Jones, 1996). The result may be a positive feedback loop in which type 2 diabetes causes cognitive impairment, which affects self-management negatively, leading to worsened health status and more impaired executive functioning and procedural learning. The crucial importance of ECF for behavior change (Goschke, 2003) makes it probable that self-management programs that rely primarily on education will be ineffective in treating people with ECF deficits. These individuals may well require greater environmental-social support and structure in order to improve adherence and stabilize or improve their condition. Otherwise, their outcomes are likely to include accelerated cognitive decline, accompanied by failures in self-management that lead to more severe disease and increased utilization of certain health services.

This is the first research report to examine relationships among diabetes, cognition, health behaviors, and health services utilization within a single community-based epidemiologic sample. Despite the significance of the findings, there were some methodologic limitations. First, although there were enough participants to test the hypothesized main effects, for certain analyses too few cases were available to yield statistically significant results (e.g., small number of tobacco users in the diabetic subsample). Second, this was an epidemiologic study with a relatively broad focus on chronic illness and disability, and health behavior measures weren't designed specifically for persons with diabetes. Finally, collection of objective data concerning health-related behaviors and health services utilization was beyond the scope of the original study, and hence these dependent variables were assessed by self-report measures. Despite these limitations, the results suggest the importance of the clinical assessment of cognition among persons with type 2 diabetes, and

they support the inclusion of measures of executive functioning and procedural learning when evaluating diabetes outcomes.

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Table 1

Hypothesis 1: Differences between Diabetic and Non-Diabetic Participants on Dependent (Cognitive) Variables (Adjusted Analyses, $n = 1,063$)

Dependent Variable	Control		Diabetes		R ²	t-value	p-value
	mean	sd	mean	sd			
Mini Mental State Exam (MMSE)	26.5	2.8	25.8	2.9	0.329	-2.04	0.042
Behavioral Dyscontrol Scale (BDS)	16.3	2.7	15.6	3.2	0.266	-2.06	0.039
Alphanumeric Sequencing	1.04	0.8	0.86	0.8	0.245	-1.70	ns
Procedural Learning	1.64	0.5	1.55	0.60	0.093	-1.97	0.050
Constructional Praxis (MMSE pentagons)	0.78	0.4	0.64	0.5	0.123	-3.92	0.0001

Table 2

Hypotheses 2 and 3: Relationships between Cognition and Health-Related Behavior, and between Cognition and Health Services Utilization, for Diabetic Participants (Adjusted Analyses, $n = 252$)

Variable	R ²	MMSE		BDS	
		t-value	p	t-value	p
Health Behavior Variables					
SAILS IADL Score	0.355	-2.43	0.016	-4.91	0.000002
SAILS Medication Management Score	0.204	-1.27	ns	-2.08	0.039
Self-Reported IADL Score	0.254	0.49	ns	-2.86	0.005
Self-Reported Medication Management	0.122	1.20	ns	-2.79	0.006
Self-Reported Meal Management	0.188	-0.43	ns	-1.97	0.050
Frequency of Tooth Brushing	0.157	1.99	0.050	-0.63	ns
Frequency of Flossing	0.171	1.44	ns	1.01	ns
Health Services Utilization Variables					
Admitted to Nursing Home 12 Months	*	1.03	ns	1.86	ns
Number of Nursing Home Admissions	0.113	-0.18	ns	-2.53	0.012
Last Nursing Home Length of Stay (LOS)	0.077	1.10	ns	-1.74	ns
Inpatient in Last 12 Months	*	0.30	ns	0.002	ns
Number Hospital Admissions 12 Months	0.139	-1.00	ns	-1.32	ns
Total Hospital LOS 12 Months	0.075	0.16	ns	0.32	ns
Number of Clinic/Emergency Visits	0.174	0.29	ns	-2.61	0.01
Number of Outpatient Visits in Last 2 weeks	0.064	0.10	ns	-0.40	ns
Home Health Episodes Last 12 Months	*	0.20	ns	1.03	ns
Number of Days Home Care 12 Months	0.29	-1.11	ns	-0.34	ns

* Logistic Regression rather than Ordinary Least Squares Regression, Wald statistic in lieu of t .