Memory Matters: Developmental Differences in Predictors of Diabetes Care Behaviors

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Objective  Longitudinal research shows that pediatric type 1 diabetes can result in verbal memory difficulties, yet the role of memory in the daily management of this or any other chronic illness has not been evaluated. Methods  Verbal memory measures from two well-standardized tests were administered to 224 youths with type 1 diabetes, aged 9 to 17. Twenty-four-hour recall interviews conducted separately with mothers and their children assessed diabetes care behaviors. Results  Rote verbal memory predicted blood glucose testing frequency for adolescents but not for preadolescents; and when combined with ethnicity, socioeconomic status, and age, rote verbal memory accounted for 27.6% of the variance, p < .001. Quantitative verbal working memory—along with ethnicity, socioeconomic status, and age, p < .01—accounted for 33.7% of the variance in predicting carbohydrate calories for older adolescents. Conclusions  Memory, in addition to demographic factors, is a significant predictor of some of the central self-care behaviors involved in diabetes management. However, memory only predicts diabetes management for older adolescents, who have greater self-care responsibility.

Key words  type 1 diabetes; insulin-dependent diabetes mellitus; adolescents; memory; self-care.

Longitudinal research shows that type 1 diabetes can result in verbal memory difficulties for youths and that these memory skills may decline or plateau with longer disease duration (Fox, Chen, & Holmes, in press; Kovacs, Ryan, & Obrosky, 1994; Northam et al., 2001; Rovet & Ehrlich, 1999). Although the mechanism of action is not well defined, various hypotheses include the adverse effect of metabolic fluctuations on the central nervous system of children under 5 or 10 years old (Northam et al., 2001); hippocampal insult secondary to hypoglycemic seizures (Hershey, Craft, Bhargava, & White, 1997); and faulty transfer of short-term verbal recall to long-term storage (Fox et al., in press).

Diminished verbal memory is a concern because memory becomes more verbal than visual throughout the school years (Schneider & Pressley, 1989), and memory difficulties may relate to declining self-care, although to our knowledge this possibility has not been examined. Delineation of the role of memory in daily care may have ramifications for clinical treatment, particularly since memory can be enhanced or compensated for with intervention (Bos & Van Reusen, 1989; Moely et al., 1986; Schneider & Pressley, 1989; Wise & Olson, 1989). The purpose of this study is to explore the possible association between verbal memory abilities and disease care behaviors in youths with type 1 diabetes.

Other neurocognitive skills, such as intelligence, problem-solving ability, and executive functioning, may also be disrupted for high-risk groups of children with diabetes (see Ryan, 1988; Ryan & Becker, 1999 for
reviews). Although these global abilities are important and may relate to overall comprehension, integration, and planning of disease care behaviors, intelligence and executive functioning are relatively resistant to remediation efforts and are less likely to benefit from clinical intervention (Bos & Van Reusen, 1989; Kershner, 1989).

In contrast, memory is a relatively discrete, malleable skill (Batchelor & Dean, 1991; Bos & Van Reusen, 1989; Brainerd & Reyna, 1989; Moely et al., 1986; Schneider & Pressley, 1989; Wise & Olson, 1989) and at its most basic level is essential to initiate a self-care behavior. Recall may be impeded when there is a disruption in daily routine or when physical cues are absent—that is, when a person is asymptomatic. Although motivational factors cannot be ruled out, patients often simply forget to take their medicine once they become symptom-free, despite their having normal intelligence. In fact, adults with a variety of chronic conditions report “forgetting” as one of the most common reasons for their failure to take medication (Atwood et al., 1992; Dunbar-Jacob & Schlenck, 2001; Walsh, Horne, Dalton, Burgess, & Gazzard, 2001).

Nevertheless, the possible association between memory and health care behaviors remains unexamined, particularly within the context of a chronic illness such as diabetes, which has significant memory demands with each of its treatment components (insulin administration, blood glucose monitoring, exercise, and diet composition). Some of these behaviors and their interrelations (e.g., blood glucose monitoring before breakfast) may become highly practiced, or “overlearned,” particularly for adults. In contrast, youths are in a state of transition, acquiring more self-care responsibility with increasing age (Drotar & levers, 1994; Ingersoll, Orr, Herrold, & Golden, 1986; La Greca, Follansbee, & Skyler, 1990; Wysocki, Meinhold, Cox, & Clarke, 1990; Wysocki et al., 1992) and having relatively less memory capacity than adults (Schneider & Pressley, 1989). Thus, diabetes care behaviors are less likely to be “automated,” or consistently performed, by youths; instead, their behaviors are more likely to be memory dependent. Assessment of verbal memory skills in relation to self-care behavior is germane in this population, due to evidence of memory’s disruption in at-risk groups (Hershey et al., 1997) as well as its decline with longer disease duration, which coincides with increasing self-care responsibility (Wysocki et al., 1990; Wysocki et al., 1992).

Different types of verbal memory are likely to be required for different diabetes tasks. Simple rote or repetitive memory should be required to initiate relatively rudimentary behaviors, such as blood glucose monitoring and remembering to eat frequently. In contrast to this simpler type of memory, more complex recall skills are likely needed for the more complicated aspects of disease care. For example, more demanding quantitative verbal working memory should be required to recall and calculate numeric caloric information, which is necessary to keep a running tally of daily dietary composition. Furthermore, adolescents, especially those using insulin pumps or multiple injections of fast-acting insulin, are instructed to compute the dietary composition of each meal, particularly carbohydrates, so that they can adjust insulin doses (Brink, 1997; Gillespie, Kulkarni, & Daly, 1998). The American Diabetes Association recommends that 50% to 60% of calories come from carbohydrates and that less than 30% come from fats (Franz et al., 2002). To achieve these goals, individuals with diabetes must continually update quantitative estimates of carbohydrates and fats ingested based on food consumed throughout the day.

The landmark Diabetes Control and Complications Trial (DCCT) indicated that following dietary recommendations 90% of the time related to better glycosylated hemoglobin levels (M = .86 percentage point lower) in comparison to following the diet less than 45% of the time (Delahanty & Halford, 1993). In turn, reductions of 1.7 percentage points in glycosylated hemoglobin levels resulted in 53% to 70% risk reductions in the progression of retinopathy and in 10% to 55% risk reductions for nephropathy (DCCT Research Group, 1994).

The large-scale DCCT also conclusively demonstrated the converse, that is, how long-term poorer metabolic control substantially increases the risk for retinopathy and nephropathy (DCCT Research Group, 1994). In addition to the possibility of disease complications, pediatric patients have historically faced a reduced life expectancy (National Institute of Diabetes and Digestive and Kidney Diseases [NIDDK], 1995). These potentially poor outcomes make it important to study factors linked to effective diabetes care. Previously, psychosocial variables such as family environment, motivational factors, and social functioning have been related to diabetes care for children (Hanson, Henggeler, & Burghen, 1987a; Jacobson et al., 1987). In contrast, cognitive variables remain unstudied, despite the presence of cognitive difficulties in a sizable proportion of children with diabetes (Holmes, Fox, Lampert, & Greer, 1999; Ryan, 1988; Ryan & Becker, 1999) and despite the relative complexity of the diabetes regimen (Holmes, 1987; Johnson et al., 1992; Johnson, Silverstein, Rosenbloom, Carter, & Cunningham, 1986).
Adolescents with diabetes are at particular risk for future disease complications because disease management (Hanson, Henggeler, & Burghen, 1987b; Jacobson et al., 1987; Johnson et al., 1992; Johnson et al., 1986; La Greca et al., 1990) and metabolic control (Jacobson et al., 1987; Johnson et al., 1992) typically begin to deteriorate when youths become 12 to 13 years old and assume more self-care responsibility (Drotar & Ievers, 1994; Ingersoll et al., 1986; La Greca et al., 1990; Wysocki et al., 1990; Wysocki et al., 1992). Ethnicity and socioeconomic status (SES) also should predict diabetes care. Adolescents of ethnic minority status perform self-care behaviors less frequently (Saucier & Clark, 1993) and are less adherent to blood glucose testing and dietary recommendations, with concurrent poorer metabolic control than Caucasian adolescents (Auslander, Thompson, Dreitzer, White, & Santiago, 1997; Delamater, Albrecht, Postellon, & Gutai, 1991; Delamater et al., 1999). Similar patterns are documented for children in families of low SES (Auslander et al., 1997). Although these demographic variables are well-established determinants of disease care and metabolic outcome (Adler et al., 1994), memory skills that are instrumental to initiating and performing diabetes care behaviors are hypothesized to predict daily disease management above and beyond demographic factors.

Links between memory and diabetes care are evaluated in the present study, using a pediatric sample during an important period of transition, from preadolescence to adolescence. Despite declining self-care behaviors throughout the pediatric years (Hanson et al., 1987b; Johnson et al., 1992; Johnson et al., 1986), it is postulated that memory should only predict diabetes management for older adolescents, who are likely to have greater self-care responsibility. Rote verbal memory is hypothesized to predict relatively simple repetitive blood glucose testing and eating frequency. Quantitative verbal working memory is expected to predict more complex dietary composition of fat and carbohydrates. Hypotheses are formulated for only these aspects of the daily treatment regimen because these are the only behaviors that have demonstrated adequate measurement reliability (Freund, Johnson, Silverstein, & Thomas, 1991; Johnson et al., 1992) to allow detection of memory effects on self-care behaviors (see the Diabetes Care Behaviors section in the Method).

Method

Participants

Youths aged 9 to 17 with type 1 diabetes and their parents were recruited from several pediatric endocrine clinics in two metropolitan areas: Washington, D.C., and Richmond, Virginia. The clinics recommended similar diabetes care regimens, including carbohydrate counting for participants using a pump or taking at least three injections of insulin per day. Children in the study had diabetes for over 6 months, had no other chronic medical conditions, had not experienced head trauma, and were not taking medications that affect the central nervous system. To rule out low ability as a factor related to poor memory or poor self-care, children were excluded from the study if they had conceptual ability below the normal range—that is, a Wechsler Intelligence Scale for Children-III (WISC-III; Wechsler, 1991), Similarities subtest score below 7—or were placed in school programming for the mentally disabled. Children with learning disabilities or other learning problems were not excluded; diabetes is associated with a higher incidence of learning difficulties (Hagen et al., 1990; Holmes et al., 1992) such that the children’s inclusion is representative of the range of cognitive functioning typically found in this population.

Sample Characteristics

The sample consisted of 224 youths with type 1 diabetes (see Table 1 for demographic and disease characteristics). No differences were found between participants at each site, except for slightly higher mean glycosylated hemoglobin values at the Richmond site ($M = 8.9\%$, $SD = 1.6$) versus the Washington, D.C. site ($M = 8.0\%$, $SD = 1.3$), $t (175) = -4.40$, $p < .001$ (two-tailed). Participants were generally in moderate metabolic control and were from middle-class families. The self-identified ethnicity variable revealed a racial distribution similar to metropolitan diabetes clinics (26% ethnic minority, see Table 1; Glasgow et al., 1991).

Procedure

Letters from endocrinologists informed families about the study, and a follow-up telephone call identified interested participants. Approximately 20% of families declined, citing primarily time demands; yet, participation rates were consistent across study sites. Assessments were most often scheduled on the day of a medical appointment. Each parent gave written and verbal informed consent, whereas each child assented to participate before being given cognitive tests by a trained psychological examiner. The tests were administered after a meal or snack to prevent hypoglycemia during the assessment. The appropriate institutional ethics committees approved the protocol.
Measures

Rote Verbal Memory
The Wide Range Assessment of Memory and Learning (Sheslow & Adams, 1990) yields a Verbal Memory index. It measures, in part, the ability to remember simple rote information after interference tasks and a significant delay. It was selected to represent the rote memory required to remember simple tasks such as blood glucose monitoring and eating frequency. The index has good reliability with a coefficient alpha of .93 and a test–retest reliability of .82 (Sheslow & Adams, 1990).

Quantitative Verbal Working Memory
The Arithmetic subtest of the WISC-III (Weschler, 1991) measures relatively complex quantitative verbal working memory (Sattler, 1992). It requires an individual to keep a store of information in short-term memory and then perform mental operations on it, such as addition (Schneider & Pressley, 1989). This task was selected to represent the more complex memory necessary to keep an ongoing tally of carbohydrates and fats consumed during the day. The subtest has good reliability, with a test–retest coefficient of .77 (Sattler, 1992).

Conceptual Intellectual Ability
The Similarities subtest of WISC-III (Wechsler, 1991) measures verbal conceptual intellectual ability and is an effective measure of general intelligence \( (r = .71 \text{ with Full-Scale Intelligence Quotient}; \) Sattler, 1992). The subtest’s test–retest coefficient of .85 shows good reliability (Sattler, 1992). There is a significant and positive correlation between conceptual ability and memory (Batchelor & Dean, 1991), making it important to include this measure to ensure that participants had broadly defined average cognitive abilities (i.e., a scaled score > 7), to rule out low functioning as a factor related to poor memory or poor self-care.

Diabetes Care Behaviors
To assess diabetes care behaviors, parents (primarily mothers) and youths completed separate 24-hour recall interviews (Johnson et al., 1986), most often at the time of the cognitive assessment. Within 2 weeks, one additional set of 24-hour recall interviews was conducted over the telephone. Each parent–child dyad reviewed the previous day in temporal sequence, from a child’s awakening to his or her retiring. This method assesses actual diabetes care behaviors—including diet, exercise, blood glucose testing, and insulin injections—over a recent time-limited interval (Johnson et al., 1986). The separate descriptions of diabetes care behaviors from two individuals (i.e., parent and youth) provides corroboration of behaviors and reduces the likelihood of systematic “halo” and source error effects. Data from the parent–child interviews were combined with decision rules described in Johnson et al. (1986). Of the 12 behavioral measures that are yielded from this technique, only blood glucose testing and dietary behaviors (i.e., eating frequency, percentage of calories from carbohydrates and fat) have acceptably high reliability coefficients over a 3-month period, thus making them reliable estimates of behaviors for the purposes of this investigation. Reliability coefficients for blood glucose testing frequency were .72 to .76, whereas the coefficients for the dietary behaviors were .45 to .77. In contrast, the exercise behaviors had correlations as low as .37 over a 3-month interval (Freund et al., 1991). It was not possible to meaningfully evaluate insulin injection behaviors, because of the highly individualized insulin treatment regimens utilized by youths in the study (i.e., two versus three injections versus the pump). Similarly, the advent of short-acting insulin has made the measure of injection–meal timing relatively obsolete.

Table I. Sample Characteristics of Demographics and Disease (N = 224)

<table>
<thead>
<tr>
<th></th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>118</td>
<td>53</td>
</tr>
<tr>
<td>Caucasian</td>
<td>166</td>
<td>74</td>
</tr>
<tr>
<td>African American</td>
<td>47</td>
<td>21</td>
</tr>
<tr>
<td>Hispanic</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Experienced severe hypoglycemic (≥ 1 episode)</td>
<td>70</td>
<td>31</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>12.90</td>
<td>1.90</td>
<td>9.00–17.00</td>
</tr>
<tr>
<td>SES (score)</td>
<td>45.70</td>
<td>11.50</td>
<td>11.00–70.00</td>
</tr>
<tr>
<td>Hba, (%)</td>
<td>8.30</td>
<td>1.60</td>
<td>5.20–15.00</td>
</tr>
<tr>
<td>Hba, (variability)</td>
<td>0.67</td>
<td>0.47</td>
<td>0.06–2.55</td>
</tr>
<tr>
<td>Severe hypoglycemic episodes (per subject)</td>
<td>1.20</td>
<td>3.70</td>
<td>0.00–30.00</td>
</tr>
<tr>
<td>Severe hypoglycemic episodes (per subject experiencing severe hypoglycemia)</td>
<td>3.80</td>
<td>6.00</td>
<td>1.00–30.00</td>
</tr>
<tr>
<td>Age of onset (years)</td>
<td>8.80</td>
<td>3.80</td>
<td>6.00–15.70</td>
</tr>
<tr>
<td>Diabetes duration (years)</td>
<td>4.20</td>
<td>3.30</td>
<td>0.50–13.30</td>
</tr>
<tr>
<td>Blood glucose testing frequency (per day)</td>
<td>3.20</td>
<td>0.95</td>
<td>0.00–5.00</td>
</tr>
<tr>
<td>Eating frequency (per day)</td>
<td>4.40</td>
<td>2.00</td>
<td>2.00–9.00</td>
</tr>
<tr>
<td>Carbohydrates (%)</td>
<td>48.90</td>
<td>8.00</td>
<td>23.30–78.50</td>
</tr>
<tr>
<td>Fats (%)</td>
<td>35.50</td>
<td>7.10</td>
<td>10.50–66.30</td>
</tr>
</tbody>
</table>

SES = socioeconomic status. Hba, = glycosylated hemoglobin.
The glycosylated hemoglobin (HbA1c) assay measures glycosylated hemoglobin indicating higher status. Parent–youth concordance rates also are stable over 3 months, indicating appropriate test–retest reliability (Freund et al., 1991).

SES
SES was assessed with the Hollingshead Four Factor Index (Hollingshead, 1975), based on parents’ occupations and highest education levels. Higher scores indicate higher status.

Glycosylated Hemoglobin
The glycosylated hemoglobin (HbA1c) assay measures glycosylated hemoglobin as an indication of metabolic control over the previous two to three months (Blanc, Barnett, Gleason, Dunn, & Soeldner, 1981). The DCA 2000 analyzer (Bayer HealthCare, Tarrytown, NY) measured glycosylated hemoglobin values at all sites. With a normal reference range of 4% to 6%, high scores reflect poor metabolic control. In addition to mean HbA1c levels, a 6-month variability index in metabolic control was also analyzed, which consisted of the standard deviation of three HbA1c values (6 months prior, 3 months prior, and the current medical appointment). Mean HbA1c reflects only average metabolic control, whereas metabolic variability is more sensitive to changes in diabetes management behaviors over time (Cox et al., 1994; Johnson et al., 1992).

Results
Hierarchical multiple regression analyses evaluated the predictive power of memory on self-care behaviors and of self-care behaviors on metabolic control, with age as a possible moderator. The moderator of youth responsibility was considered initially, as measured by the Diabetes Family Responsibility Questionnaire (DFRQ; Anderson, Auslander, Jung, Miller, & Santiago, 1990), but a kappa of .32 indicated low agreement between parent and child reports regarding youth self-care responsibility. The questionnaire also lacks items specific to daily dietary behaviors. Thus, rather than DFRQ scores, age was used as a more stable indicator of child responsibility for diabetes care based on parents’ and pediatric endocrinology specialists’ reports of child independence in performing disease management behaviors (Wysocki et al., 1992). In addition to this large-scale epidemiologic survey (Wysocki et al., 1992), other studies show greater diabetes self-care responsibility for older adolescents (Drotar & Ievers, 1994; Ingersoll et al., 1986; La Greca et al., 1990). Demographic variables (ethnicity, SES, and age) were additional predictors to control for the variables’ well-known effects on self-care and health status (Adler et al., 1994; Auslander et al., 1997; Delamater et al., 1991; Delamater et al., 1999; Saucier & Clark, 1993). Ethnicity was a dichotomous variable: a zero (0) represented ethnic minority status, and a one (1) represented Caucasian.

Rote Verbal Memory and Blood Glucose Testing/Eating Frequency
To test the hypothesis that simple rote verbal memory would predict rudimentary blood glucose monitoring and eating frequency, a hierarchical multiple regression analysis was conducted for the total sample. Both the rote Verbal Memory index (M = 100, SD = 15) and the demographic variables significantly predicted blood glucose testing, $R^2 = .17, F (4, 219) = 11.43, p < .001$. Because age as a moderator was of interest and because there is a fairly discrete transfer of blood glucose testing responsibility to adolescents by the time they reach 12 to 13 years old (La Greca et al., 1990; Wysocki et al., 1990; Wysocki et al., 1992), the entire sample was dichotomized into adolescents (> 12.5 years, n = 125) or preadolescents (≤ 12.5 years, n = 99). Exploratory analyses supported this data analytic strategy, as adolescents (> 12.5 years) in the current sample performed significantly more blood glucose tests independently (M = 49.9%) than did preadolescents (M = 37.2%; $t (193) = 3.19, p < .01$ (two-tailed). In addition to the significant full model, $R^2 = .19, F (5, 218) = 7.53, p < .001$, the age moderator (Age × Verbal Memory Index Product Term) was significant, $β = 1.01, t (223) = 2.18, p < .05$. For adolescents, but not for preadolescents, Figure 1 regression lines show that rote verbal memory predicted blood glucose testing frequency.

Because only adolescents showed a relation between memory and daily blood glucose testing frequency, as hypothesized, their performance was evaluated further. A separate regression with rote memory and the demographic predictors accounted for 27.6% of the variance in explaining blood glucose testing, $F (4, 119) = 11.31, p < .001$ (see Table II). Rote verbal memory uniquely accounted for 5.5% of the variance, $t (123) = 3.00, p < .01$. Better rote memory predicted more daily blood glucose tests, and, more important, poorer rote memory related
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to fewer daily blood glucose tests (see Figure 1). Caucasian ethnicity and younger age also positively predicted daily blood glucose monitoring, uniquely accounting for 3% and 10% of the variance, respectively. For preadolescents, the model was not significant.

In similar analyses to test the hypothesis that rote verbal memory would predict relatively rudimentary eating frequency (number of meals and snacks per day), no significant results were obtained for either group of children.

Quantitative Verbal Working Memory and Diet

The hypothesis that more complex quantitative verbal memory would predict more favorable levels of carbohydrate and fat ingestion, per the American Diabetes Association guidelines, was tested with another hierarchical multiple regression analysis, conducted for the entire sample. First, to standardize diet composition across individuals within the sample, fat and carbohydrate consumption was calculated for each youth as a percentage of total calories ingested (Freund et al., 1991; Johnson et al., 1986; Reynolds et al., 1990). For the total sample, a model including Arithmetic score (quantitative working memory, M = 10, SD = 3), the age moderator (Age × Arithmetic Score Product Term), and the demographic variables predicted percentage of calories from carbohydrates, \( R^2 = .06, F(5, 218) = 2.96, p < .05 \). Because dietary self-care responsibility is transferred gradually (La Greca et al., 1990; Wysocki et al., 1990; Wysocki et al., 1992), age was represented as a continuous moderator showing significance, \( \beta = 1.08, t(223) = 2.10, p < .05 \). For older adolescents only (one standard deviation above the mean, \( \geq 14.8 \) years, \( n = 39 \)), regression lines in Figure 2 reveal that quantitative working memory predicted percentage of carbohydrate calories as hypothesized.

For older adolescents, a separate model including Arithmetic quantitative memory and the demographic predictors explained 33.7% of the variance for calories from carbohydrates, \( R^2 = .33, F(4, 35) = 4.46, p < .01 \) (see Table III). More important, quantitative memory was the only significant predictor, \( t(39) = 2.29, p < .05 \), uniquely accounting for 9.9% of the variance, more than the combined demographic variables (8.9%). Better quantitative memory predicted more carbohydrate consumption, and conversely, poorer memory predicted fewer carbohydrate calories.

For preadolescents (< 13 years, \( n = 120 \)), a separate regression was not significant, although the model for middle adolescents (13–14.7 years, \( n = 65 \)) approached significance in predicting calories from carbohydrates, \( R^2 = .14, F(4, 61) = 2.52, p = .05 \).
Next, a separate hierarchical multiple regression analysis was conducted to evaluate whether complex working memory predicted dietary fat composition. For the entire sample, a model including quantitative verbal working memory and the demographic variables predicted fat calories, \( R^2 = .05, F(4, 219) = 2.63, p < .05 \). However, only SES showed a trend toward significance, \( t(223) = -1.77, p = .08 \), whereas the other predictors in the model were not significant. An exploratory analysis supported the proposition of the relative de-emphasis in tracking dietary fat, compared to carbohydrates, concurrent with increases in the use of subcutaneous insulin pumps for adolescents (Brink, 1997; Gillespie et al., 1998). In the present study, participants on the pump consumed proportionally more carbohydrates (\( M = 52.2\%, SD = 10.1 \)) than those utilizing insulin injections (\( M = 48.2\%, SD = 7.3 \)), \( t(222) = 2.37, p < .05 \) (two-tailed), but there was no relation between pump use and fat consumption.

### Conceptual Intelligence and Diabetes Care Behaviors

To ensure that memory, and not underlying conceptual intellectual ability, was the significant factor related to disease management, exploratory hierarchical multiple regression analyses were conducted with Similarities scores, the memory variables, and the demographic factors as predictors. The model predicted daily blood glucose tests, \( R^2 = .17, F(5, 218) = 9.20, p < .001 \); and verbal memory remained a significant predictor, \( \beta = .21, t(223) = 2.77, p < .01 \). However, conceptual intellectual ability did not predict blood glucose testing frequency. Similarly, the model predicted carbohydrate calories, \( R^2 = .06, F(5, 218) = 2.66, p < .05 \). Quantitative working memory was a significant predictor, \( \beta = .17, t(223) = 2.10, p < .05 \), whereas conceptual ability was not.

### Diabetes Care Behaviors and Glycosylated Hemoglobin

The relation between the moderated diabetes care behaviors (i.e., blood glucose monitoring and carbohydrate consumption) and average level of metabolic control was assessed with a hierarchical multiple regression analysis conducted for the whole sample to determine if memory made a difference in metabolic control. None of the diabetes care behaviors in the study predicted mean glycosylated hemoglobin levels averaged over the previous 6 months.

Next, the relation between moderated diabetes care behaviors was evaluated in relation to the variability index for metabolic control in the total sample, with a

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**Table III.** For Older Adolescents, Hierarchical Multiple Regression Analysis Predicting Carbohydrate Calories (\( N = 39 \))

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unstandardized Regression Coefficient</th>
<th>SE</th>
<th>( \beta )</th>
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</thead>
<tbody>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td>−.16</td>
<td>2.96</td>
<td>−.01</td>
</tr>
<tr>
<td>SES</td>
<td>.43**</td>
<td>.15</td>
<td>.43</td>
</tr>
<tr>
<td>Age</td>
<td>−3.81</td>
<td>2.15</td>
<td>−.26</td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td>−.77</td>
<td>2.96</td>
<td>−.04</td>
</tr>
<tr>
<td>SES</td>
<td>.23</td>
<td>.15</td>
<td>.23</td>
</tr>
<tr>
<td>Age</td>
<td>−3.41</td>
<td>2.15</td>
<td>−.23</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>0.97*</td>
<td>.43</td>
<td>.38</td>
</tr>
</tbody>
</table>

\( R^2 = .24 \) (\( p < .05 \)) for Step 1; \( R^2 = .34 \) (\( p < .01 \)) and \( \Delta R^2 = .10 \) (\( p < .05 \)) for Step 2. Ethnicity was coded dichotomously: a zero (0) represented ethnic minority status, and a one (1) represented Caucasian. SES = socioeconomic status.

*\( p < .05 \).
**\( p < .01 \).
***\( p < .001 \).
hierarchical multiple regression analysis to determine if memory made a difference in metabolic control variability. The Hba1c variability index over 6 months was significantly predicted by blood glucose testing and the demographic variables, $R^2 = .06$, $F(4, 161) = 2.73, p < .05$. Because of the discrete transfer of blood glucose testing (La Greca et al., 1990; Wysocki et al., 1990; Wysocki et al., 1992), the age moderator was again dichotomized into adolescence (> 12.5 years) or preadolescence (≤ 12.5 years). In addition to the significant full model, $R^2 = .10$, $F(5, 160) = 3.67, p < .01$, the age moderator (Age × Blood Glucose Testing Frequency Product Term) was significant, $β = .72$, $t(165) = 2.66, p < .01$. For preadolescents, but not for adolescents, Figure 3 regression lines show that daily blood glucose tests predicted the Hba1c variability index.

For preadolescents ($n = 99$), a separate model with blood glucose testing and the demographic variables predicted 18.8% of the variance for the Hba1c variability index, $F(4, 73) = 4.22, p < .01$. Blood glucose testing, the only significant predictor, uniquely explained a majority (15.2%) of the variance, $t(77) = −3.69, p < .001$. More daily blood glucose tests predicted less variability in glycosylated hemoglobin, and conversely, fewer blood glucose tests predicted more metabolic variability. For adolescents, the difficulty of achieving metabolic stability during puberty may have obscured the association, for the model was not significant.

**Discussion**

The current findings show that memory predicts some central, daily self-care behaviors and is sensitive to developmental differences in this pediatric type 1 diabetes sample. Psychosocial variables have traditionally been related to diabetes management for adolescents (Hanson et al., 1987a; Jacobson et al., 1987); however, the current findings demonstrate that cognitive predictors of self-care behaviors also may warrant research and clinical attention.

For adolescents (> 12.5 years), verbal memory uniquely accounts for 5.5% of the variance for daily blood glucose tests. Although adolescent ethnicity accounts for 3% of the variance for blood glucose monitoring, memory is nonetheless a significant, malleable variable that can offset the decline in self-care behaviors typically found during the adolescent years (Hanson et al., 1987b; Johnson et al., 1992; Johnson et al., 1986) and confirmed in the present regression analysis with a negative beta between older adolescent age and testing frequency. Equally important, the relation between blood glucose monitoring and memory independent of conceptual ability indicates that memory’s unique association with this self-care skill is above and beyond conceptual ability and the well-known effects of demographic variables (Adler et al., 1994, Auslander et al., 1997; Saucier & Clark, 1993). However, eating frequency is not predicted by memory, and the reason for this is presently unclear. Variables outside the scope of this study, such as level of family organization and lifestyle factors, may predict frequent meals and snacks instead of simply remembering to eat. In contrast, individuals must depend on memory associations to initiate blood glucose testing before different meals and snacks each day (i.e., breakfast and dinner one day; lunch and evening snack the next) as instructed by endocrinologists to provide an optimal diurnal profile.

Responsibility for relatively complex dietary behaviors is gradually transferred to youths throughout
adolescence (La Greca et al., 1990; Wysocki et al., 1990; Wysocki et al., 1992). For older adolescents (≥ 14.8 years), quantitative working memory is the only significant predictor of carbohydrates consumed, and it accounts for 9.9% of the variance, compared to 8.9% of the variance accounted for by the nonsignificant demographic predictors combined. As expected, these findings indicate that remembering and calculating continual daily carbohydrate consumption is a complex task that is heavily memory-dependent. In contrast, the smaller, predictive effect of memory for simpler initiation of blood glucose monitoring, the predictive effect of memory with greater behavioral complexity for calculation of carbohydrate consumption carries important clinical implications as more adolescents are prescribed the subcutaneous pump and must calculate boluses based on carbohydrates consumed or exercise, or both (Brink, 1997; Gillespie et al., 1998). Similarly, as diabetes management becomes more personalized yet complicated, future research may focus on other cognitive skills, such as problem solving and cognitive flexibility, which are likely needed to appropriately optimize among self-care behaviors.

Previous research shows that independence for dietary self-care, the more cognitively demanding task of those presented, is achieved at an older age (La Greca et al., 1990; Wysocki et al., 1990; Wysocki et al., 1992). Maintenance of a fund of basic nutritional information, monitoring meal composition, and tracking quantitative totals ingested throughout the day all depend on complex quantitative working memory. Like rote memory, working memory can offset the decline in self-care skills typically occurring during adolescence (Hanson et al., 1987b; Jacobson et al., 1987; Johnson et al., 1992; Johnson et al., 1986; La Greca et al., 1990), further strengthening the potential significance of this finding and highlighting a possible point of clinical prevention or intervention. Because some investigators have found that verbal memory declines with disease duration (Fox et al., in press; Kovacs et al., 1994; Northam et al., 2001; Rovet & Erlich, 1999), it will be important to follow children longitudinally to assess the relative buffer that memory may continue to provide for self-care behaviors—that is, if memory does indeed decline over time.

In contrast, quantitative memory did not predict dietary fat consumed by older adolescents, likely because of its relative de-emphasis compared to carbohydrates in current clinical practice. Carbohydrate counting, in which patients are explicitly taught to quantify carbohydrate intake to calculate insulin dosages, has increased significantly and in parallel with increases in the use of subcutaneous insulin pumps in youths (Brink, 1997; Gillespie et al., 1998). In the present study, participants on the pump consistently consumed proportionally more carbohydrates than those utilizing insulin injections. In contrast to the immediate need to count carbohydrates, monitoring dietary fat is desirable to minimize distal cardiovascular complications but, in the short term, is unnecessary to modify insulin doses or prevent metabolic crises.

As hypothesized, memory predicted disease care behaviors only in adolescents because adolescents have more responsibility for disease management (Drotar & Ievers, 1994; Ingersoll et al., 1986; La Greca et al., 1990; Wysocki et al., 1990; Wysocki et al., 1992). Congruently, adolescents (> 12.5 years) in the present sample performed more blood glucose tests independently than did preadolescents. For preadolescents and younger children, whose parents perform or assist with the majority of blood glucose tests, the memory ability of parents, rather than that of youths, may relate to daily blood glucose testing frequency.

In contrast to blood glucose testing, more complicated dietary care is managed for a longer time by parents, who transfer responsibility to youths more gradually throughout adolescence (La Greca et al., 1990; Wysocki et al., 1990; Wysocki et al., 1992). Only for the older adolescents in the sample (≥ 14.8 years), who are most likely to have autonomy for food selection outside the family home, did quantitative working memory predict calories consumed from carbohydrates. Similar trends of more self-care responsibility with older age are found in other pediatric illnesses such that memory may also exert age-dependent effects with different diseases (Drotar & Ievers, 1994; McQuaid et al., 2001; Wade, Islam, Holden, Kruzon-Moran, & Mitchell, 1999). By extension, working memory is likely to relate even more strongly to dietary and other self-care behaviors for adults with diabetes, who are entirely responsible for their disease management. Furthermore, memory’s predictive effect on disease management behaviors also may exist for adults with other chronic conditions, such as type 2 diabetes, hypertension, and cardiovascular disease, which require multiple, daily self-care behaviors, including dietary monitoring and medical management.

One potential limitation of this study is that age was used to estimate youth self-care responsibility (see Results section for rationale). Although there are undoubtedly individual variations from the age sequence of independence for self-care behaviors agreed on by parents and
endocrinology specialists (Wysocki et al., 1992), age nonetheless provides a reliable and generalizable method by which to measure group differences. Age may be particularly useful in studies such as this, with relatively larger sample sizes. Alternatively, future studies may create new measures of diabetes responsibility with items that are carefully matched to desired outcome behaviors to provide a more sensitive indicator of self-care responsibility, especially for smaller-scale studies that may require greater measurement specificity.

For preadolescents with diabetes, more blood glucose testing predicts less variability in glycosylated hemoglobin, as would ideally be expected. However, in adolescents, blood glucose testing does not relate to less variability in glycosylated hemoglobin values, probably because of physiological changes that accompany puberty—specifically, increased insulin resistance, hormonal fluctuations (Amiel, Sherwin, Simonson, Lauritano, & Tamborlane, 1986), and disrupted lipid metabolism (Cruickshanks, Orchard, & Becker, 1985). Adults with diabetes, who have relatively stabilized post-pubertal hormonal status, should show the expected associations among better memory, more blood glucose tests, and low variability in metabolic control.

In sum, the present results suggest that memory is a significant factor related to developmental differences in the successful performance of certain self-care behaviors for type 1 diabetes. Memory appears to operate along a continuum and serves as an asset that can offset declining self-care behaviors during adolescence. Evaluation of the role of memory in self-care skills appears warranted in further studies. More important, memory can be improved by teaching strategies to facilitate recall (Batchelor & Dean, 1991; Bos & Van Reusen, 1989; Brainerd & Reyna, 1989; Moely et al., 1986; Schneider & Pressley, 1989; Wise & Olson, 1989) or by using external aids, such as wristwatches with alarms, to prompt blood glucose testing. Calculators with memory capability could aid in dietary monitoring, particularly if they are preprogrammed with the nutrient content of frequently eaten foods. Parents also may use wireless technology, such as beepers or text messaging, to remind children to test blood glucose levels.

In addition to replicating these findings, further research could explore the link between memory and self-care skills in adults with diabetes as well as evaluate memory in the daily management of other chronic illnesses. Finally, other cognitive skills, most notably problem-solving ability, might prove to be an important cognitive skill to warrant additional study, whereas parent memory skills may predict diabetes care behavior in preadolescents and school age youths. As children with diabetes and other chronic conditions live longer (NIDDK, 1995), comprehensive delineation of predictors of better disease management, including cognitive variables, can help ensure the quality of a longer life (Hoey et al., 2001; Rubin & Peyrot, 1999).

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