

## Prospective Study

# Perception of difficulty and glucose control: Effects on academic performance in youth with type I diabetes

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## Abstract

**AIM:** To investigate whether perceptions of task difficulty on neuropsychological tests predicted academic achievement after controlling for glucose levels and depression.

**METHODS:** Participants were type 1 diabetic adolescents, with a mean age = 12.5 years (23 females and 16 males), seen at a northwest suburban Chicago hospital. The sample population was free of comorbid clinical health conditions. Subjects completed a three-part neuropsychological battery including the Digit Symbol Task, Trail Making Test, and Controlled Oral Word Association test. Following each task, individuals rated task difficulty and then completed a depression inventory. Performance on these three tests is reflective of neuropsychological status in relation to glucose control. Blood glucose levels were measured immediately prior to and after completing the neuropsychological battery using a glucose meter. HbA1c levels were obtained from medical records. Academic performance was based on self-reported grades in Math, Science, and English. Data was analyzed using multiple regression models to evaluate the associations between academic performance, perception of task difficulty, and glucose control.

**RESULTS:** Perceptions of difficulty on a neuropsychological battery significantly predicted academic performance after accounting for glucose control and depression. Perceptions of difficulty on the neuropsychological tests were inversely correlated with academic performance ( $r = -0.48$ ), while acute (blood glucose) and long-term glucose levels increased along with perceptions of task difficulty ( $r = 0.47$ ). Additionally, higher depression scores were associated

with poorer academic performance ( $r = -0.43$ ). With the first regression analysis, perception of difficulty on the neuropsychological tasks contributed to 8% of the variance in academic performance after controlling for peripheral blood glucose and depression. In the second regression analysis, perception of difficulty accounted for 11% of the variance after accounting for academic performance and depression. The final regression analysis indicated that perception of difficulty increased with peripheral blood glucose, contributing to 22% of the variance. Most importantly, after controlling for perceptions of task difficulty, academic performance no longer predicted glucose levels. Finally, subjects who found the cognitive battery difficult were likely to have poor academic grades.

**CONCLUSION:** Perceptions of difficulty on neurological tests exhibited a significant association with academic achievement, indicating that deficits in this skill may lead to academic disadvantage in diabetic patients.

**Key words:** Type 1 diabetes; Adolescents; Perception of difficulty; Academic performance; Glucose control

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**Core tip:** The objective of the current study was to investigate the association between perceptions of difficulty and academic performance in adolescents with type 1 diabetes. Perceptions of difficulty are reflected in executing cognitive activities as well as in the task of glucose regulation. Glucose control needs to be understood, not so much from a biological perspective but as an effortful process that is also reflected in academic challenges. The problem of anergia observed generally in patients with diabetes seems to broadly affect a variety of tasks and challenges. Thus, the novelty of the study is in showing that the regulation of glucose in diabetic patients is another example of the broad challenges confronted in the life of patients with diabetes.

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## INTRODUCTION

Type 1 diabetes is one of the most common chronic diseases of childhood. In the United States, type 1 diabetes affects approximately 1 in 300 children and is usually diagnosed between the ages of 5 and 11 years<sup>[1,2]</sup>. The course of this autoimmune version of diabetes is characterized by ongoing beta cell destruction

and the need for exogenous insulin<sup>[3]</sup>. Since the central nervous system (CNS) is dependent on a supply of glucose for normal neural functioning, reduced glucose concentrations may result in temporary and/or enduring impairments in CNS function<sup>[4]</sup>. Dysregulation of the CNS may have negative effects on neuropsychological functioning, such as impaired memory, attention, motor skills, and executive functioning<sup>[5]</sup>.

Adolescents with type 1 diabetes face many challenges that can impact metabolic control along with physiological and psychological complications. The need for adherence to metabolic control and compliance with regimen is effortful. Beyond the demands for medical compliance, adolescents are often burdened by depression<sup>[6]</sup> as well as anergia<sup>[7]</sup> and thus may be at academic disadvantage<sup>[8]</sup>.

Along with academic adversity, individuals with type 1 diabetes may be challenged by self-evaluative factors such as the perception of control, which affects behavioral and social functioning<sup>[9,10]</sup>. The literature has described three prominent types of control: perceived control, perceived confidence (self efficacy), and perceived difficulty<sup>[11]</sup>. Perceived difficulty, a subjective experience, can be defined as the extent to which individuals believe that performance on a task or behavior would range from easy to difficult<sup>[11]</sup>. If adolescents believe they are substandard at a task because of its difficulty, they are likely to devalue the activity and decrease effort expenditure<sup>[12]</sup>.

Perceived difficulty has also been shown to relate to an individual's beliefs regarding how much effort is needed to succeed at a task and whether success is possible<sup>[13]</sup>. The effort expended in performing a task is predicted to increase proportionally with the level of perceived task difficulty<sup>[14]</sup>. Indeed, effort has been associated with academic performance. Studies<sup>[15]</sup> have found that self-reported grades are positively correlated with effort. Moreover, adherence to regimen<sup>[16]</sup> and metabolic control<sup>[17]</sup> also reflect the expenditure of effort. Therefore, poor glucose control may be positively correlated with perceptions of task difficulty and inversely associated with academic performance<sup>[18]</sup>. Indeed, self-control and willpower are both functions of available glucose levels<sup>[19]</sup>. Thus, glucose control and effort are two highly related processes that need to be differentiated.

Perceptions of difficulty rely on executive functioning skills, such as problem solving and decision-making. These skills require an individual to make a decision regarding the degree of difficulty associated with the task and whether he or she will be successful in carrying out the task. Since problem solving and decision-making skills contribute to academic performance, these executive functioning skills may be impaired in diabetic individuals<sup>[20]</sup>. A meta-analytic finding indicated that children with type 1 diabetes performed slightly, yet significantly, lower on attention/executive functioning tasks than non-diabetic individuals<sup>[21]</sup>. This finding, in turn, was associated with poor glucose control and

hypoglycemic episodes as well<sup>[21]</sup>.

To open the question of effort, three brief but well validated neuropsychological tests were administered<sup>[22]</sup> and participants rated the difficulty of each test. Secondly, academic performance and depression levels were evaluated and analyzed. Since long-term glucose control (HbA1c) is associated with cognition<sup>[18]</sup>, HbA1c levels from within the past three months were collected from medical records. Acute glucose levels immediately prior to and following neuropsychological testing were also collected and evaluated. These procedures enabled the distinction between the assessment of effort-associated processes supporting academic and neuropsychological processes vs those putatively supporting glucose control.

## MATERIALS AND METHODS

### Participants

This study was designed as a cross-sectional, prospective study. Participants were type 1 diabetic patients who attended a diabetes clinic in a northwest suburban Chicago hospital. Adolescents were approached to participate in the study during their regularly scheduled doctor's appointment. Adolescents were excluded from participation if they had co-morbid clinical health conditions, such as asthma, anemia, vascular disease, kidney disease, chronic tiredness, depression, psychiatric history, or obesity. Parents of the patients filled out consent forms that outlined the procedure and risks of participation. The subjects also signed an assent form. The study measures were carried out in a quiet, separate room for each participant individually. Pre-doctoral psychology students administered the assessments. Participants were provided modest monetary compensation for participation in the study. There were a total of 39 participants, consisting of 23 females and 16 males. The population was comprised of 71.8% Caucasian, 20.5% Hispanic, 5.1% Asian, and 2.6% African American. The mean age of the participants was 12.5 years (SD = 2.73). This study was approved by the Institutional Review Board at Rosalind Franklin University as well as the hospital's review board. There is no conflict of interest related to this study.

### Materials

**Glucose control:** Blood glucose measurements were performed immediately prior to administering and again after completing the neuropsychological battery with glucose meters (One Touch, Blood Glucose Monitoring System). This procedure was used to obtain an average peripheral blood glucose measurement. A single HbA1c level was recorded from the medical records retrieved from the previous three months, prior to testing.

**Neuropsychological battery:** The neuropsychological battery included the Digit Symbol task (Wechsler Intelligence Scale for Children-Forth Edition), Trail Making test Parts A and B, and Controlled Oral Word

Association (COWA) in that order. This three-part neuropsychological battery was selected because the tests are brief, well researched, psychometrically sound, and are commonly used<sup>[23]</sup>. Performance on these tests is reflective of neuropsychological status in diabetic patients in relation to glucose control<sup>[22]</sup>.

The Digit Symbol task of the Wechsler Intelligence Scale for Children-Fourth Edition (DS; WISC-IV)<sup>[24]</sup> was used to assess psychomotor performance, attention, memory, and perceptual organization. It consists of Coding and Incidental Learning. In Coding, the individual was presented with several rows of a series of numbers (1 through 9). Each number was paired with a corresponding unique symbol. The individual was asked to fill in as many symbols as possible in boxes directly under the corresponding number and was allowed 120 s to complete this task. In Incidental Learning, individuals were asked to carry out two tasks: to recall as many digit-symbol pairs as possible (Pairing) and to recall as many symbols as possible without the corresponding numbers (Free Recall). Internal consistency of the Digit Symbol Coding task is 0.85.

The Trail Making Test<sup>[23]</sup> was used to assess attention, visual-motor tracking, and speed of information processing. It consists of two parts: in Part A, individuals were asked to draw a line that accurately connected the correct sequence of numbers as quickly as possible. In Part B, individuals were asked to draw a line that accurately connects the correct sequence of numbers and letters in an alternating pattern as quickly as possible. Reliability for Part A is 0.78 and for Part B 0.67.

The COWA test<sup>[25]</sup> assessed verbal functions. Individuals were asked to generate as many words as possible that began with the letter S in 60 s and then the letter F in 60 s as the examiner recorded these. Test-retest reliability is 0.88 and inter-scorer reliability was almost perfect.

**Rating of task difficulty:** After completing three tasks (the Digit Symbol task of the Wechsler Intelligence Scale for Children-Fourth Edition, Trail Making test Part A and B, and Controlled Oral Word Association test), participants were asked to rate the level of perceived difficulty of each task on a scale from 1-5, where 1 = very easy and 5 = very difficult. These evaluations were summed and averaged to develop a task difficulty measure.

**Academic performance:** Participants self reported academic grades in several courses during the current school year: Math, Science, and English. For the purposes of tabulation, grades were converted into a scale score from 1-5, where 1 = F, 2 = D, 3 = C, 4 = B, and 5 = A. Grades were then averaged for each participant.

**Depression:** To avoid possible reactive effects<sup>[26]</sup>, participants were lastly administered the Children's Depression Inventory (CDI)<sup>[27]</sup> which is a 27 item self report inventory used to measure depressive symp-

**Table 1** Characteristics of participants

	Mean	SD
Disease duration (mo)	48.05	41.08
BMI (kg/m <sup>2</sup> )	21.18	3.85
Peripheral blood glucose (mm/dL)	190.99	89.27
HbA1c (%)	8.39	1.63
Digit symbol coding	55.38	14.7
Digit symbol paring	11.44	5.16
Digit symbol free recall	7.38	1.41
Trails A (s)	39.67	19.02
Trails B (s)	92.74	64.84
COWA	20.26	6.62
CDI	7.23	5.54
Perception of difficulty <sup>1</sup>	10.15	2.95
Grades <sup>2</sup>	4.1	0.77

<sup>1</sup>Range 1-20; <sup>2</sup>Range low to high; 1-5. BMI: Body mass index; HbA1c: Hemoglobin A1c; COWA: Controlled Oral Word Association; CDI: Child depression inventory.

tomatology in youth aged 7-17. Respondents indicated which of three options best represented their mood in the context of everyday life: absence of symptom = 0; mild symptom = 1; and definite symptom = 2. The CDI provides a total score on five domains of depression. The reliability coefficient for the total inventory was 0.86<sup>[27]</sup>.

Data was collected and entered into Statistic Package for Social Science (SPSS) Version 13. Zero order correlation tables were examined to assess the degree of relationship between the variables. *P*-values of less than 0.05 were considered statistically significant. Multiple regression analyses were used to assess outcome variables.

## RESULTS

Basic description of the sample population is presented in Table 1. The primary results (Table 2) indicated that perceptions of difficulty on the neuropsychological tests were inversely correlated with academic performance ( $r = -0.48$ ), while acute (blood glucose) and long-term glucose levels (HbA1c) increased along with perceptions of task difficulty ( $r = 0.47$ ). Finally, higher depression scores were associated with poorer academic performance ( $r = -0.43$ ).

To evaluate the relationship of difficulty on neuropsychological tests and academic performance after controlling for peripheral glucose levels and depression, a multiple regression analysis was conducted (Table 3). The predictors in the regression analysis were entered in the following order: (1) peripheral blood glucose; (2) CDI; and (3) perception of difficulty with academic performance as the dependent variable. Results from the first predictor indicated that as peripheral blood glucose increased, academic performance decreased. The second predictor (CDI) indicated that increasing depression was associated with poorer academic performance after controlling for peripheral blood glucose. Lastly, the third predictor (perception of difficulty) showed

that higher levels of difficulty perceived on the neuropsychological test was inversely associated with academic performance after taking into account peripheral blood glucose and depression. The result of this analysis indicated that the perception of difficulty on the neuropsychological tasks contributed to 8% of the variance in academic performance after controlling for peripheral blood glucose and depression. Thus, stronger ratings of laboratory task difficulty were associated with poorer academic performance.

After controlling for academic performance and depression, a regression analysis was conducted with peripheral blood glucose as the dependent variable to test if perceptions of task difficulty were associated with glucose levels (Table 4). The predictors in the regression analysis were entered in the following order: (1) academic performance; (2) CDI; and (3) perceptions of difficulty on the neurological tests with peripheral blood glucose as the dependent variable. Results indicated that the first predictor (higher academic performance) was inversely related to peripheral blood glucose, contributing to 14% of the variance. The second predictor (CDI) showed that the levels of depression had insignificant effects on peripheral blood glucose. The third predictor (perception of difficulty) showed that the higher level of difficulty perceived on the test accounted for the higher peripheral blood glucose level. Perception of difficulty accounted for 11% of the variance after accounting for academic performance and depression. This indicated that higher perceptions of task difficulty were associated with higher blood glucose levels while depression seemed to play no significant role in this model. Individuals, who perceived the neuropsychological battery as challenging, may also experience difficulty controlling glucose levels.

The purpose of the final analysis (Table 5) was to determine whether academic performance would predict glucose levels after controlling for perceptions of task difficulty. The order of predictors was: (1) perception of difficulty; (2) academic performance; and (3) CDI with peripheral glucose levels as the dependent variable. The first predictor (perception of difficulty) showed that perception of difficulty increased with peripheral blood glucose, contributing to 22% of the variance. Most importantly, after controlling for perceptions of task difficulty, academic performance no longer predicted glucose levels. Additionally, it was found that the level of depression was not associated with peripheral glucose levels. Results from Table 5 indicated that peripheral blood glucose was positively correlated with the perception of task difficulty.

## DISCUSSION

The general purpose underlying this research was to critically evaluate the various explanations for the problems that diabetic adolescents experience in the performance of cognitive tasks. In addition to elevations



**Table 2 Correlations among the variables**

	Academic performance	HbA1c	Peripheral blood glucose	CDI	Perceptions of difficulty
Academic performance <sup>1</sup>	-	-0.26	-0.37 <sup>a</sup>	-0.43 <sup>b</sup>	-0.48 <sup>b</sup>
HbA1c		-	0.42 <sup>b</sup>	0.03	0.34 <sup>a</sup>
Peripheral blood glucose <sup>2</sup>			-	0.22	0.47 <sup>b</sup>
CDI <sup>3</sup>				-	0.27

<sup>1</sup>Low scores indicate poor grades; <sup>2</sup>Low score-lower glucose levels; <sup>3</sup>Higher scores more depression. <sup>a</sup> $P < 0.05$ ; <sup>b</sup> $P < 0.01$ . HbA1c: Hemoglobin A1c; CDI: Child depression inventory.

**Table 3 Linear multiple regression analysis for variables predicting academic performance<sup>1</sup>**

	$\beta$	R <sup>2</sup> change
Peripheral blood glucose <sup>2</sup>	-0.37	0.14 <sup>a</sup>
Child depression inventory <sup>3</sup>	-0.36	0.12 <sup>a</sup>
Perceptions of difficulty on neurological tests	-0.33	0.08 <sup>a</sup>

<sup>1</sup>Low scores indicate poor grades; <sup>2</sup>Low score-lower glucose levels; <sup>3</sup>Higher score more depression. <sup>a</sup> $P < 0.05$ .  $\beta$ : Standardized coefficient beta.

**Table 5 Linear multiple regression analysis for variables predicting peripheral blood glucose<sup>1</sup>**

	$\beta$	R <sup>2</sup> change
Perceptions of difficulty on neurological test	0.47	0.22 <sup>b</sup>
Academic performance <sup>2</sup>	-0.18	0.03
Child depression inventory <sup>3</sup>	0.05	0.00

<sup>1</sup>Low score-lower glucose levels; <sup>2</sup>Low scores indicate poor grades; <sup>3</sup>Higher scores more depression. <sup>b</sup> $P < 0.01$ .  $\beta$ : Standardized coefficient beta.

in blood glucose, there are two alternatives, namely anergia<sup>[7]</sup> and depression<sup>[6]</sup>. Since these processes each exacerbate or contribute to the diminution of effort, it is possible that the actual mediator of compromised cognition can be found in reduced effort. Thus, the primary purpose of this introductory study was to assess the contribution of effort<sup>[14]</sup> to both metabolic control and reduced cognition in these patients.

Through a series of multiple regression analyses, the results showed that after controlling for levels of effort, the role of metabolic control was compromised with respect to cognition. A key assumption in this process is that metabolic control is per se an effortful process. If effort is viewed as the primary process, metabolic control remains as an adjunctive player in cognition.

To examine this model, we turn to the results of the multiple regression analyses presented earlier. That is, adolescents who perceived the neuropsychological battery as more difficult were more likely to have lower grades in Math, Science, and English. Thus, perceiving the battery as difficult may indicate a broad weakness in executive functioning skills, such as problem solving and decision-making. Furthermore, increased levels of depression also negatively contributed to academic performance. As a result, academic performance was

**Table 4 Linear multiple regression analysis for variables predicting peripheral blood glucose<sup>1</sup>**

	$\beta$	R <sup>2</sup> change
Academic performance <sup>2</sup>	-0.37	0.14 <sup>b</sup>
Child depression inventory <sup>3</sup>	0.08	0.01
Perceptions of difficulty on neurological test	0.38	0.11 <sup>b</sup>

<sup>1</sup>Low score-lower glucose levels; <sup>2</sup>Low scores indicate poor grades; <sup>3</sup>Higher scores more depression. <sup>b</sup> $P < 0.01$ .  $\beta$ : Standardized coefficient beta.

poorer in adolescents with elevated peripheral blood glucose, which in itself may be a reflection of the difficulty or effort necessary for exercising metabolic control.

This study provided insight into how academic performance may be associated with self-ratings of difficulty on neuropsychological tasks after controlling for blood glucose levels and depression. Further, the study showed how peripheral blood glucose levels can be derived from perceptions of difficulty based on neuropsychological testing after controlling for academic performance and depression. Each of these observations will be discussed serially.

Previous findings<sup>[28,29]</sup> have suggested a relationship between glucose control and academic performance. Greater difficulty in maintaining strong glucose control was associated with poorer academic performance. The list of predictors of academic performance included a neuropsychological battery that assessed psychomotor performance, attention, memory, speed of information processing, and verbal functioning.

Participants who perceived the neuropsychological battery as difficult were also more likely to exhibit poor grades (Table 4). However, this finding may not be surprising, since performance on the neuropsychological battery and academic performance share some conceptual space. Thus, a basic question in this study is whether the commonly observed relationship between glucose levels and cognitive functioning represents a basic physiological relationship between glucose and neuropsychological functioning? Alternatively, is the index of glucose control merely a reflection of the basic challenge between compliance with regimen, an effort-demanding task, and the challenge intrinsic to the cognitive task?

After controlling for appraisals of task difficulty, blood glucose levels seem to no longer account for cognitive

performance once task difficulty is factored into the equation (Table 5). Finally, by eliminating the influence of perceptions of difficulty in maintaining blood glucose control and complying with medical regimen, peripheral blood glucose and academic performance were no longer significantly related.

This may be the first study to illustrate how perceptions of task difficulty on neuropsychological tests are associated with poor academic performance in diabetic patients. While several studies have reported that individuals with diabetes exhibit relatively poor academic performance, the present study identifies how perceptual evaluative factors diminish academic performance.

Thus, careful disease management is needed to prevent or effectively treat potentially life-threatening complications such as hypoglycemia, diabetic ketoacidosis, and hyperglycemia as well as effort.

Limitations to the study include a relatively small sample size as well as the use of a single item to assess perceptions of task difficulty. However, this method of assessing perceptions of difficulty with one item was also utilized in a previous study<sup>[11]</sup>. In their study, Rogers and colleagues assessed self-efficacy, perceived control and perceived difficulty with the use of a single item Likert scale question for each construct<sup>[11]</sup>. Therefore, single item indicators may be regarded as similarly robust as multiple item indicators<sup>[30,31]</sup>. Lastly, academic performance was assessed by participant self-report. Systematic biases may influence the validity of self-reported grades, but self-reported grades generally predict outcomes as effectively as actual or objectively culled grades<sup>[32]</sup>.

In conclusion, this study demonstrated that perceptions of task difficulty can predict academic difficulty in a sample of diabetic adolescents. Task difficulty was also associated with the relationship between glucose levels and academic performance. Hence, perceptions of difficulty can be viewed as a generalized executive function. When individuals perceive a task as more difficult, this may promote academic disadvantage along with increased challenges in controlling glucose. Overall, such information may be useful in training and counseling students in enhancing academic success and performance as well as in assistance with disease control.

## COMMENTS

### Background

Type 1 diabetes is one of the most common chronic diseases of childhood. In the United States, type 1 diabetes affects approximately 1 in 300 children and is usually diagnosed between the ages of 5 and 11 years.

### Research frontiers

Adolescents with type 1 diabetes face many challenges that can impact metabolic control along with physiological and psychological complications. Cognitive functioning is an important aspect of life and can be impaired in individuals with diabetes. Academic performance in diabetic adolescents may also be compromised due to fluctuations in glucose.

### Innovations and breakthroughs

Along with academic adversity, individuals with type 1 diabetes may be

challenged by self-evaluative factors such as the perception of control, which affects behavioral and social functioning. Perceived difficulty has also been shown to relate to an individual's beliefs regarding how much effort is needed to succeed at a task and whether success is possible. Perceptions of difficulty rely on executive functioning skills, such as problem solving and decision-making. Since problem solving and decision-making skills contribute to academic performance, these executive functioning skills may be impaired in diabetic individuals. The current study sought to examine the role of effort on glucose and academic performance.

### Applications

This may be the first study to illustrate how perceptions of task difficulty on neuropsychological tests are associated with poor academic performance in diabetic patients. While several studies have reported that individuals with diabetes exhibit relatively poor academic performance, the present study identifies how perceptual evaluative factors diminish academic performance.

### Terminology

Diabetes mellitus is a major health problem in the United States affecting approximately 29.1 million people. There are two major classifications of diabetes: insulin dependent diabetes (type 1) and non-insulin dependent diabetes (type 2). Diabetes is a group of metabolic diseases that either cause defects in insulin action, insulin secretion, or a combination of both, resulting in hyperglycemia. Perceived difficulty, a subjective experience, can be defined as the extent to which individuals believe that performance on a task or behavior would range from easy to difficult.

### Peer-review

The study addresses a relevant scientific question and is well-conducted. The results are significant indicating that deficits in perception of difficulty may lead to academic disadvantage in diabetic patients. The manuscript is interesting and may provide important information for the reader of the journal.

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