EVALUATION OF A THEORETICAL MODEL OF PERCEPTUAL ACCURACY AND SELF-MANAGEMENT BEHAVIOR IN PEDIATRIC DIABETES

A Dissertation

by

MARIELLA M. LANE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2005

Major Subject: Psychology

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ABSTRACT

Evaluation of a Theoretical Model of Perceptual Accuracy and Self-Management Behavior in Pediatric Diabetes. (August 2005)

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This study evaluated a model of perceptual accuracy and self-management behavior in pediatric diabetes. Participants were 169 children and adolescents (10-18 years) attending diabetes summer camps. Error grid analysis quantified global perceptual accuracy and specific blood glucose estimation errors. The mean accuracy index was 15%, failure to detect hyperglycemia being the most frequent error. Path analysis evaluated models for failure to detect hypoglycemia, failure to detect hyperglycemia, and overestimation of normal blood glucose. Results reflected relatively good fit of the data with the models; however, results did not support mediational hypotheses and explained minimal variance in perceptual error. In sum, participants made considerable estimation errors that may affect self-management; however, results did not support the theoretical models in this sample.

ACKNOWLEDGMENTS

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I would also like to express appreciation to the American Diabetes Association for permitting this study to be conducted at ADA sponsored camps. Thanks also to Texas Lions Camp of Kerrville, TX; Camp Sandcastle of Corpus Christi, TX; and Camp Endres of Davis, Oklahoma for allowing recruitment of participants.

Lastly, I would like to express appreciation to individuals at Texas A&M University who were integral in the completion of this project: my dissertation committee, the members of the TAMU Pediatric Psychology Research Team, and to all undergraduate students who assisted in data collection and data entry.

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INTRODUCTION

Self-Management in Diabetes

Diabetes treatment regimens are complex, multi-faceted, and are likely to vary both across and within patients from day to day. Patients with diabetes are responsible for daily diabetes management, requiring active patient involvement (Gonder-Frederick & Cox, 1991). The typical self-management regimen consists of four primary components: insulin administration (i.e., appropriate amount and timing of insulin), testing blood glucose level and/or testing urine for ketones, specific dietary behaviors (i.e., frequency, timing, amount, and types of food), and regular exercise (Bradley, Pierce, Hendrieckx, Riazi, & Barendse, 1998). Diabetes self-management is not a unitary construct, and the level engagement in one type of self-management behavior does not necessarily relate to level of engagement in another type (Ruggiero & Javorsky, 1999).

Definition of Symptom Perception

Conceptual definition of symptom perception. Researchers have defined symptom perception as the perceptual and cognitive processes underlying conscious awareness of a physical symptom and associated sensations (Rietveld, 1998; Rietveld & Brosschot, 1999; Rietveld, Kolk, Prins, & Colland, 1997), or as "the patient's consciously appreciated sensation of a physiologic problem (Banzett, Dempsey,

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This dissertation follows the style and format of *Journal of Pediatric Psychology.*

O'Donnell, & Wamboldt, 2000, p. 1178)." Simply put, symptom perception refers to detection of symptoms of a physical problem, perceptual accuracy being the characteristic of interest.

Symptom perception defined in the context of diabetes. In line with this conceptual definition, one can define symptom perception in diabetes as conscious awareness of or ability to detect physical sensations associated with hypo- and hyperglycemia (e.g., pounding heart, dizziness). Literature on perceptual inaccuracy in diabetes typically only refers to under-perception of symptoms of low blood glucose, termed hypoglycemia unawareness. However, Kovatchev, Cox, Gonder-Frederick, Schlundt, and Clarke (1998) indicated that it is possible to detect no symptoms of hypoglycemia (i.e., under-perception) and to experience symptoms at normal blood glucose levels (i.e., over-perception).

Importance of Perceptual Accuracy

Recognition and interpretation of physical symptoms influences illness behaviors such as self-diagnosis, medical help-seeking, health care decision-making and self-treatment processes. Perceptual accuracy is important with regard to medical management, self-management, adherence, morbidity, mortality, and is a potential target for treatment. Both over- and under-perception of symptoms could result in serious medical consequences and self-management errors.

Assessment of Perceptual Accuracy in Diabetes

Research with illnesses such as asthma often assesses symptom perception by comparing the subjective self-report of a patient's perceived symptoms (e.g., breathlessness) to an objective measure of functioning (e.g., peak expiratory flow rate). The corollary in diabetes would be comparison of symptoms of blood glucose fluctuations (e.g., shakiness) to objective blood glucose, but use of this symptom intensity method is limited because the pattern of symptoms an individual experiences in relation to blood glucose level is highly idiosyncratic. Both hypo- and hyperglycemia can be symptomatic, but no specific set of symptoms reliably covaries with blood glucose across patients. Further, some symptoms can relate to hypoglycemia for some individuals and hyperglycemia for others. Table 1 provides symptoms that tend to covary with hypoglycemia, hyperglycemia, and those that relate to both. For most patients, hypoglycemia is more symptomatic than hyperglycemia (Gonder-Frederick & Cox, 1991).

Assessment of perceptual accuracy can also compare an observed measure of functioning (e.g., blood glucose) to estimated functioning predicted by the patient (e.g., patient prediction of blood glucose). Initially, data analysis consisted of examining the mean correlation between a patient’s estimated and observed functioning over numerous trials. Then Cox et al. (1989) introduced error grid analysis as an approach to quantifying perceptual accuracy that accounts for the relative clinical importance of perceptual errors. The error grid approach involves plotting estimated blood glucose against observed blood glucose over successive trials and observing the clinically meaningful zone into which plots fall. This method yields the frequency of clinically accurate estimates as well as the frequency of benign errors and clinically important errors (i.e., failure to detect hypo- and hyperglycemia, estimation of these states when

Table 1

Trends in Covariation of Symptoms with Blood Glucose Levels

Hypoglycemia	Hyperglycemia	Hypoglycemia and Hyperglycemia
Trembling	Dry mouth	Blurry vision
Sweating	Thirst	Fatigue
Pounding Heart	Alert or energetic	Weakness
Confusion	Sweet taste in mouth	Heavy breathing
Slurred Speech	Tingling or pain in extremities	Nausea
Hunger	Frequent urination	Headache
Uncoordination	Stomach cramps	Frustration
Anxiety		Irritation
		Dizziness

Note. From "Symptom Perception, Symptom Beliefs, and Blood Glucose Discrimination in the Self-Treatment of Insulin-Dependent Diabetes," by L. A. Gonder-Frederick & D. J. Cox, 1991, in J. A. Skelton, & R. T. Croyle (Eds.), *Representations in Health and Illness,* p. 229. Copyright 1991 by Springer-Verlag. Reprinted with permission.

one is euglycemic, and mistaking hypo- for hyperglycemia and vice versa). Computation of an accuracy index (AI) includes subtracting the summed percentage of clinically significant errors from the summed percentage of accurate estimates. A high, positive AI is desirable, with an AI of zero reflecting equal numbers of accurate and inaccurate estimates and a negative AI reflecting more clinically significant inaccurate estimates than accurate ones.

Research Quantifying Perceptual Accuracy in Diabetes

Many individuals come to recognize their idiosyncratic symptoms but others are not able to recognize cues of hypoglycemia (Bradley et al., 1998). Most patients with diabetes believe that they can recognize symptoms associated with blood glucose fluctuations. Unfortunately, confidence in the ability to detect hypo- and hyperglycemia does not predict accuracy, and patients are often not aware of their inability (Gonder-Frederick & Cox, 1986; Gonder-Frederick & Cox, 1991).

Ability to estimate blood glucose levels accurately varies greatly across adult patients, with clinically accurate estimates from error grid analysis typically ranging from 42 to 90%. Error grid analyses indicate that adults make clinically serious errors up to 20% of the time (Cox et al., 1985). Across studies, failure to detect extreme levels of blood glucose is consistently the most common clinically serious error in both adults and children (Kovatchev et al., 1998). Individuals tend to normalize their estimate of blood glucose, overestimating blood glucose when it is low and underestimating it when it is high (Moses & Bradley, 1985).

Adolescent patients also vary considerably in their ability to estimate their blood glucose level, but they are significantly less accurate in blood glucose estimation than are adults. Freund and colleagues (1986) reported that in 25 adolescents with insulin-dependent diabetes mellitus (IDDM) the average correlation between actual and estimated blood glucose was .51, with 72% of adolescents having statistically significant correlations. The accuracy index from error grid analysis averaged 25%. (Freund, Bennett-Johnson, Rosenbloom, Alexander, & Hansen, 1986).

Ruggiero, Kairys, Fritz, and Wood (1991) examined the accuracy of blood glucose estimates in a sample of 70 adolescents (11-15 years) with IDDM using both a correlation approach and error grid analysis. The mean overall accuracy index was 7%, with approximately 34% of patient estimates being accurate, 39% inaccurate but clinically benign, and 27% inaccurate and clinically relevant. The majority of clinically relevant errors consisted of misestimating high blood glucose or low blood glucose as normal. Using the correlational approach, the mean correlation was .29 with 52% of adolescents having correlations greater or equal to .30 and 17% greater or equal to .50. Adolescents in Ruggiero, Kairys, et al.'s (1991) study were less accurate on both correlational and error grid indices of accuracy than those in the Freund et al. (1986) study, perhaps due to reinforcement for estimate accuracy used in the latter study.

In an intervention study of eight young adults and nine adolescents, Nurick and Johnson (1991) reported a 32% average accuracy index for the young adults and a 7% mean accuracy index for the adolescents. In another sample of 35 adolescents with IDDM, accuracy indices for blood glucose estimation ranged from -7% (more inaccurate than accurate estimations) to 82%, with a mean of 38% (Wiebe, Alderfer, Palmer, Lindsay, & Jarrett, 1994).

Ryan and colleagues (2002) used a more stringent criterion for accuracy in their adolescent and young adult sample, defining accurate estimates as those within 10% of the observed value. During euglycemia, 38% of the participants were accurate, whereas 28% were accurate during induced mild hypoglycemia. Those who were inaccurate tended to estimate their blood glucose as euglycemic when it was hypoglycemic (Ryan, Suprasongsin, Dulay, & Becker, 2002).

In their sample of 78 adolescents, Meltzer and colleagues (2003) reported a mean accuracy index of 37.0% with 24.1% of estimates being clinically significant errors (Meltzer, Bennett-Johnson, Pappachan, & Silverstein, 2003). Contrary to other studies, the most common type of error in this sample was misestimation of normal blood glucose likely to lead to over-corrective treatment (10.8%), with a mean of 9.1% for failure to detect hypo- or hyperglycemia and a mean of 4.2% for mistaking hypo- for hyperglycemia and vice versa.

Gonder-Frederick, Snyder, and Clarke (1991) found that younger children (5-11 years) also provided poor estimates of blood glucose (mean accuracy index of 29%; error index 35%), with results indicating that they often make clinically significant errors at the same frequency as accurate estimates. Overall, these studies reflect that diabetic patients of all ages make potentially serious errors in perception of blood glucose levels but that children and adolescents are especially at risk (Gonder-Frederick & Cox, 1991).

Introduction of the Proposed Model

Presented here for the first time is a conceptual model integrating: (a) perceptual accuracy with self-management behavior and (b) anxiety, coping style, attentional style, and self-efficacy with both of those constructs. Most research on variables related to perceptual accuracy in diabetes has studied global perceptual accuracy and has neglected the study of different perceptual errors. The present study distinguishes between types of perceptually inaccurate errors for a more fine-tuned examination. Figure 1 provides a general pictorial representation of the theoretical model; however, some differences in paths and predicted direction of relationships occur in the error-specific models.

Perceptual Accuracy and Self-Management Behavior

Expectations of diabetes patients typically include the appropriate timing and dosage of interventions, appropriate adjustment of interventions, and initiation of a variety of important self-management behaviors for both prevention and at the detection of a problem. Early detection of hypo- and hyperglycemic symptoms, awareness of blood-glucose fluctuations, and the ability to discriminate variations in blood glucose from euglycemia are necessary for appropriate diabetes self-management to occur (Cox et al., 1989; Cox, Gonder-Frederick, Antoun, Cryer, & Clarke, 1993; Schandry, Leopold, & Vogt, 1996). IDDM patients make critical daily self-management decisions based on their subjective estimates of their blood glucose levels, and even those who use self-monitoring of blood glucose tend to treat themselves for hypoglycemia based on perceived symptoms without first verifying the low blood glucose level through objective self-measurement (Cox et al., 1989; Cox et al., 1991; Gonder-Frederick &

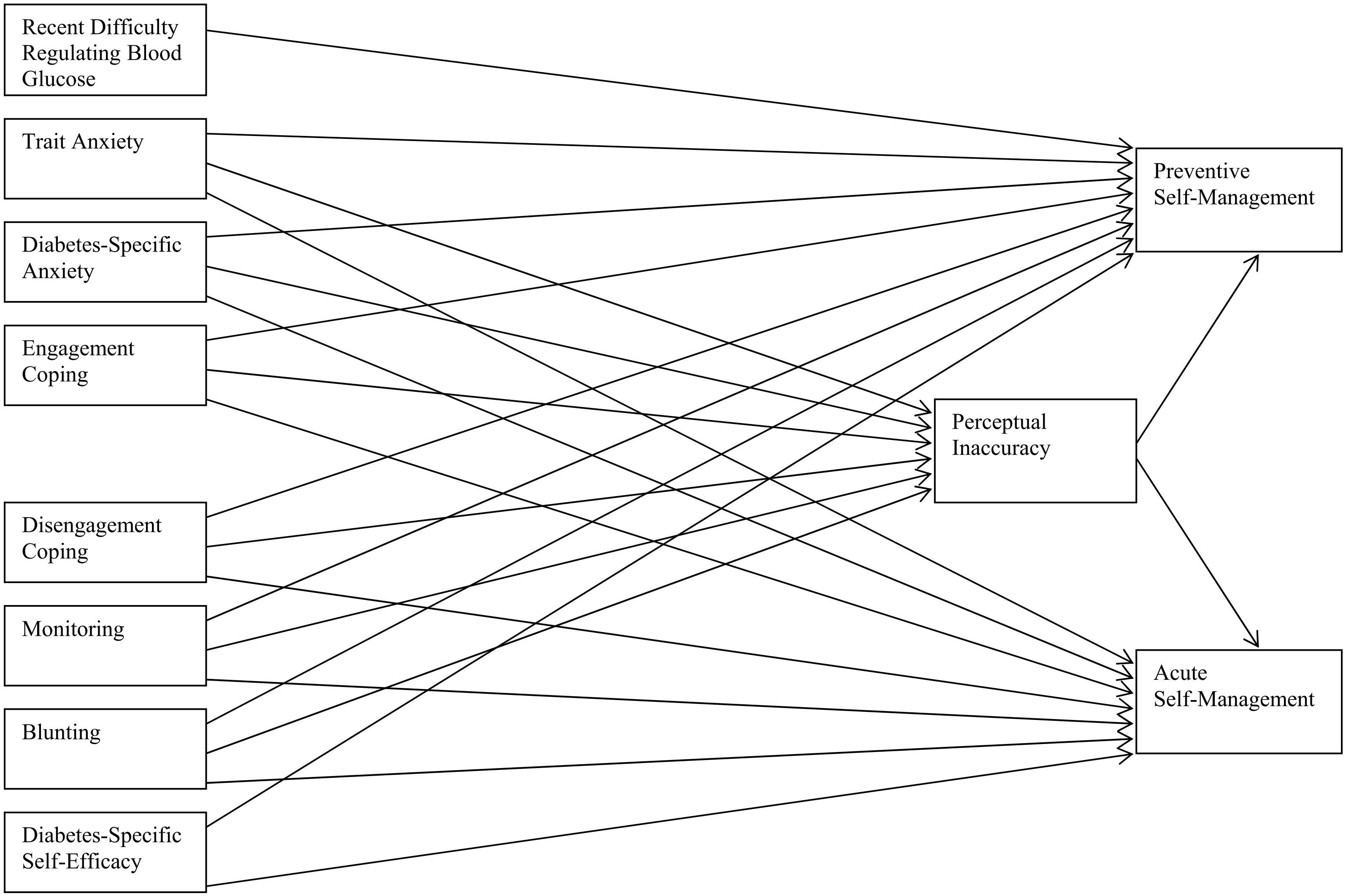

Figure 1. Proposed theoretical model of perceptual inaccuracy and self-management behavior in pediatric diabetes.

Cox, 1986). Perceptual accuracy is thus important to facilitate appropriate self-management, whereas perceptual inaccuracy may disrupt self-management and, depending on the error, could lead to either over- or under-treatment (Cox et al., 1991; Gonder-Frederick & Cox, 1991).

Kovatchev et al. (1998) postulated a model of symptomatic behavioral self-regulation in the context of detection and treatment of hypoglycemia. The model consists of the following sequence: internal condition (low blood glucose) → symptom perception (perception of one or more symptoms of low blood glucose) → appraisal (subjective estimate of one's blood glucose level) → decision (whether or not to initiate treatment). Thus, in the context of low blood glucose, the path to adaptive behavior is to perceive symptoms accurately, to estimate blood glucose correctly based on these symptoms, and to choose an appropriate treatment behavior based on that appraisal. Kovatchev and colleagues indicated that the simplest path to maladaptive behavior would be failure to perceive symptoms, leading to inaccurate blood glucose estimation and then to inappropriate decision-making.

Trait Anxiety and Perceptual Accuracy

Cox and colleagues (1993) indicated that arousal has a curvilinear relationship with symptom detection, with both low and high arousal impairing detection. Anxiety may be a form of arousal with the potential to affect perceptual accuracy. Watson and Pennebaker's (1989) symptom perception hypothesis suggests that high levels of anxiety may increase the probability of interpreting symptoms as signs of pathology, which may lead to over-perception (i.e., misestimation of euglycemia as hypo- or hyperglycemia).

A dearth of research exists on the relationship between trait anxiety and perceptual accuracy in diabetes. Polansky, Davis, Jacobson, and Anderson (1992) reported a significant correlation between trait anxiety and difficulty discriminating symptoms of hypoglycemia from those of anxiety. Cox et al. (1985) also reported a negative relationship between dispositional tendency to somatically experience anxiety and blood glucose estimation accuracy. Wiebe et al. (1994) reported that in adolescents with IDDM, higher trait anxiety was associated with reduced accuracy in discerning which symptoms covaried with one's BG fluctuations, due to a tendency to over-interpret symptoms not empirically associated with BG. However, trait anxiety did not predict estimation accuracy. In contrast, Ryan et al. (2002) reported that anxiety during euglycemia was associated with better detection of hypoglycemia symptoms and more accurate blood glucose estimation.

Trait Anxiety and Self-Management Behavior

Research has indicated that a curvilinear relationship between neuroticism and adherence behavior exists, suggesting that trait anxiety may be related to self-management (Wiebe & Christensen, 1996). Results have not been entirely consistent with regard to trait anxiety and diabetes management, but trait anxiety has correlated with indices of poor blood glucose control (Wiebe et al., 1994). In Wiebe et al.'s (1994) study with adolescents, the combination of higher trait anxiety and internal attentional focus was associated with poorer blood glucose control. However, these data did not support attribution of this interaction to blood glucose estimation accuracy.

Fear of Hypoglycemia and Perceptual Accuracy

Hypoglycemia can cause a variety of immediate and aversive consequences that may be symptomatic, affective, cognitive, or social, in addition to serious physiological consequences such as coma or death (Gonder-Frederick & Cox, 1991). Diabetic patients learn through experience and education that hypoglycemia symptoms may result in these consequences and may develop a fear or even phobic avoidance of hypoglycemia (Cox, Irvine, Gonder-Frederick, Nowacek, & Butterfield, 1987).

Polansky and colleagues (1992) hypothesized that individuals fearful of hypoglycemia might be more likely to confuse symptoms of anxiety with symptoms of hypoglycemia (e.g., pounding heart, sweaty, trembling). In accordance with their hypothesis, worry about hypoglycemia was positively associated with difficulty in differentiating anxiety and hypoglycemic symptoms in an adult sample with Type I diabetes. However, measurement of symptom discrimination ability used a single, face-valid, self-report item that more accurately reflects one's confidence in symptom discrimination ability.

Fear of Hypoglycemia and Self-Management Behavior

Fear of hypoglycemia may be a major barrier to diabetes self-management and a predictor of poor metabolic control (Cox et al., 1987). Motivation to avoid aversive hypoglycemic episodes may interfere with appropriate self-management and cause some individuals with diabetes to maintain elevated blood glucose levels. Little research has addressed this hypothesis, and research using concurrent measures of hypoglycemic fear and self-management behaviors is needed (Irvine, Cox, & Gonder-Frederick, 1992).

Because adherence to intensive diabetes management may result in increased incidence of hypoglycemia, fear of hypoglycemia may be associated with nonadherence to the insulin regimen (Ruggiero & Javorsky, 1999). However, indifference to hypoglycemia is not desirable either, as it could also jeopardize health, and a moderate level of fear of hypoglycemia is probably optimal (Cox et al., 1987; Gonder-Frederick & Cox, 1991).

Coping Style and Perceptual Accuracy

No research has investigated coping style and perceptual accuracy in diabetes.

Coping Style and Self-Management Behavior

Approach or problem-focused strategies are preferable when an illness is amenable to such efforts, and active coping may be necessary for adherence to regimens with high patient controllability because appropriate action is contingent on approach (Christensen, Benotsch, Wiebe, & Lawton, 1995; Roth & Cohen, 1986). In contrast, the use of avoidance coping strategies might lead to minimization of problems and failure to implement necessary treatment behaviors (Hansen et al., 1989). In light of the potential impact of patient behavior on diabetes management and the degree of self-management activity required by the patient, approach strategies would likely lead to increased self-management behavior in diabetes.

Few studies have examined the potential link between coping style and self-management in diabetes, but some have found a relation between coping styles and regimen adherence or glycemic control. Peyrot, McMurry, and Kruger (1999) reported evidence that coping has an indirect relationship with glycemic control, mediated by regimen adherence. Research on children with diabetes has also supported a relationship between coping skills and self-management behaviors (Ruggiero & Javorsky, 1999).

In general, problem-oriented coping styles appear to be adaptive whereas employing denial is associated with poorer diabetes regimen adherence, but results have varied. Toobert and Glasgow (1991) reported that in prospective analyses of an adult sample, diabetes problem-solving behaviors were significant predictors of dietary and exercise self-management behaviors at 6-month follow-up but did not significantly predict glucose testing. In a study of adolescents, Hanson and colleagues (1989) reported that the use of ventilation and avoidance as a coping style related negatively to adherence, whereas the utilization of personal and interpersonal resources was not associated with adherence. Further, Delamater and colleagues (1987) reported that in their sample of adolescents with Type I diabetes, those with poorer glycemic control employed more wishful thinking and avoidance/help-seeking during a stressful event in the past month than did those in good control (Delamater, Kurtz, Bubb, White, & Santiago, 1987). Use of disease-specific measures of coping is rare, and their incorporation would benefit future research.

Attentional Style and Perceptual Accuracy

When an individual is threatened with an aversive event, information processing can vary across two dimensions: (a) monitoring, or the extent to which one cognitively selects, scans for, attends to, and amplifies information signaling threat, and (b) blunting, or the extent to which one cognitively distracts from threat-relevant information (Miller, Brody, & Summerton, 1988). High monitors characteristically seek information and low blunters characteristically avoid distraction; these individuals show a preference for cues about threat. In contrast, low monitors characteristically avoid information, and high blunters characteristically distract themselves (Miller, 1987).

Such dispositional differences also include the degree to which individuals actively seek, amplify, and process health-relevant information. High monitors scan for health threats and attend to bodily cues and symptoms. High monitors and low blunters may have a lower threshold for perceiving internal bodily cues because of their propensity to scan for and attend to threat-relevant cues. Thus, individuals with these styles may be more inclined to detect changes in physical symptoms, especially if such changes may signify threat (Miller et al., 1988). Monitors may be more alert to changes in physical state, increasing their rate of symptom identification (Steptoe & O'Sullivan, 1986).

Research has indicated that monitoring for cues of threat activates anxiety and prolonged arousal, and high monitors may employ defensive strategies such as denial or disengagement (avoidant ideation) in attempt to suppress such anxiety. However, these strategies often are not successful in modulating high arousal (Miller, Rodoletz, Schroeder, Mangan, & Sedlacek, 1996). In contrast, blunters tend to deny the existence of threatening physical cues and thus do not attend to or assimilate information signifying health threat. One could speculate that an individual with diabetes who has a disposition to monitor may be more accurate at detecting symptoms because of the propensity to scan for them; or, extremely high monitoring may result in over-perception of symptoms. An individual with a blunting disposition may be less accurate at detecting symptoms and under-perceive them. A moderate amount of monitoring seems likely to be most adaptive, whereas blunting may reduce accuracy. However, no research has incorporated attentional style into perceptual accuracy research in diabetes.

Attentional Style and Self-Management Behavior

High monitors consider themselves to be vulnerable, are sensitive to cues of illness, are likely to seek medical care for less serious medical concerns and to over-utilize medical resources, engage in more preventive health behaviors than blunters, tend to overestimate the severity of health problems, and demonstrate greater distress during medical procedures (Christensen, Moran, Lawton, Stallman, & Voigts, 1997; Miller et al., 1988; Steptoe & O'Sullivan, 1986). Miller and colleagues (1988) suggested that increased medical resource utilization might occur because high monitors are more likely to scan their bodies and perceive emerging physical symptoms more quickly. With regard to blunting, those with a disposition toward this style tend to deny the existence of threatening physical cues and thus do not attend to threatening symptoms. Anxiety is not evoked, and sense of invulnerability may preclude engagement in health behaviors (Miller, Roussi, Caputo, & Kruus, 1995; Miller, Shoda, & Hurley, 1996). In sum, it seems intuitive that those with a monitoring disposition may engage in increased self-management behavior whereas those employing a blunting style may exhibit poorer self-management behavior, and perceptual accuracy may mediate these relationships (Miller et al., 1988).

However, the relationship between monitoring style and adjustment to chronic illness is less clear than for acute events. Some research suggests that the prolonged distress experienced by monitors and their tendency to resort to avoidant coping strategies in the face of chronic health threats may undermine adherence to medical regimens (Christensen et al., 1997; Miller et al., 1988; Miller, Rodoletz et al., 1996). Further, Miller and colleagues (1988) reported evidence that high monitors desire a less active role in their own health care and tend to maintain a passive role in health care decisions and treatment delivery, which may be especially problematic for those with a medical regimen with substantial self-management demands (Christensen et al., 1997).

To complicate the issue further, little work has assessed dispositional monitoring in children and adolescents. Whereas monitoring in adults predicts poorer adaptation to threatening medical procedures and conditions, information seeking in children has been associated with adaptive coping (Miller et al., 1995).

Self-Efficacy and Perceptual Accuracy

Gonder-Frederick and Cox (1991) suggested that cognitive and perceptual processes are likely to affect symptom perception, and perceiving that symptoms are absent has implications for feelings of self-efficacy. Therefore, under-perception of symptoms may serve to increase self-efficacy, but self-efficacy may not impact perceptual accuracy. No research has investigated the relationship between self-efficacy and symptom perception in diabetes.

Self-Efficacy and Self-Management Behavior

The Health Belief Model, a conceptual model for predicting adherence to a medical regimen, postulates that adherence increases as a patient experiences greater self-efficacy, or perceived ability to perform regimen tasks correctly (Becker, Drachman,

& Kirscht, 1972). Despite its potential relevance, there is little work investigating self-efficacy and self-management in individuals with diabetes.

Research suggests that higher self-efficacy relates to increased diabetes adherence in both adolescents and adults (Griva, Myers, & Newman, 2000; Kavanagh, Gooley, & Wilson, 1993). Griva and colleagues (2000) reported that adolescent participants classified as adherent to dietary recommendations and those with good adherence to blood glucose monitoring had stronger diabetes-specific self-efficacy and stronger beliefs that their illness is amenable to control than those less adherent to these regimen tasks. Ott and colleagues (2000) also reported that adherence to the diabetes regimen was related to higher diabetes-specific self-efficacy in adolescents (Ott, Greening, Palardy, Holderby, & DeBell, 2000).

Hypotheses

The primary intent of the present study was to empirically evaluate the proposed theoretical model of perceptual accuracy and self-management behavior in a sample of children and adolescents with diabetes, examining the mediating perceptual errors of (a) failure to detect hypoglycemia, (b) failure to detect hyperglycemia, (c) underestimation of a normal blood glucose as hypoglycemic, and (d) overestimation of a normal blood glucose as hyperglycemic. The model of underestimation of normal blood glucose as hypoglycemic was omitted because no individual in the sample made this error. The structure of the remaining three models is similar for each, with some variation in paths and the nature of the predicted variable relationships, as based on previous research and theory. In accordance with the proposed model, the following hypotheses were submitted:

Hypotheses for all models (see Figures 2, 3, and 4):

The exogenous variables of recent difficulty regulating blood glucose, trait anxiety, fear of hypoglycemia, engagement coping, disengagement coping, monitoring, blunting, and diabetes self-efficacy will be directly related to preventive self-management behavior. Recent difficulty regulating blood glucose, engagement coping, monitoring, and self-efficacy will be related to increased preventive self-management behavior, whereas trait anxiety, fear of hypoglycemia, disengagement coping, and blunting will be related to decreased preventive self-management.

Hypotheses for failure to detect hypoglycemia (see Figure 2):

1. Disengagement coping and blunting will be related to increased failure to detect hypoglycemia, whereas trait anxiety, fear of hypoglycemia, engagement coping, and monitoring will be related to reduced detection failure. Recent difficulty regulating blood glucose and diabetes self-efficacy will not be related to failure to detect hypoglycemia.
2. Fear of hypoglycemia, engagement coping, monitoring, and diabetes self-efficacy will be related to increased hypoglycemic episode self-management behavior, whereas trait anxiety, disengagement coping, and blunting will be related to decreased hypoglycemic self-management behavior. Recent difficulty regulating blood glucose will not relate to hypoglycemic episode self-management.

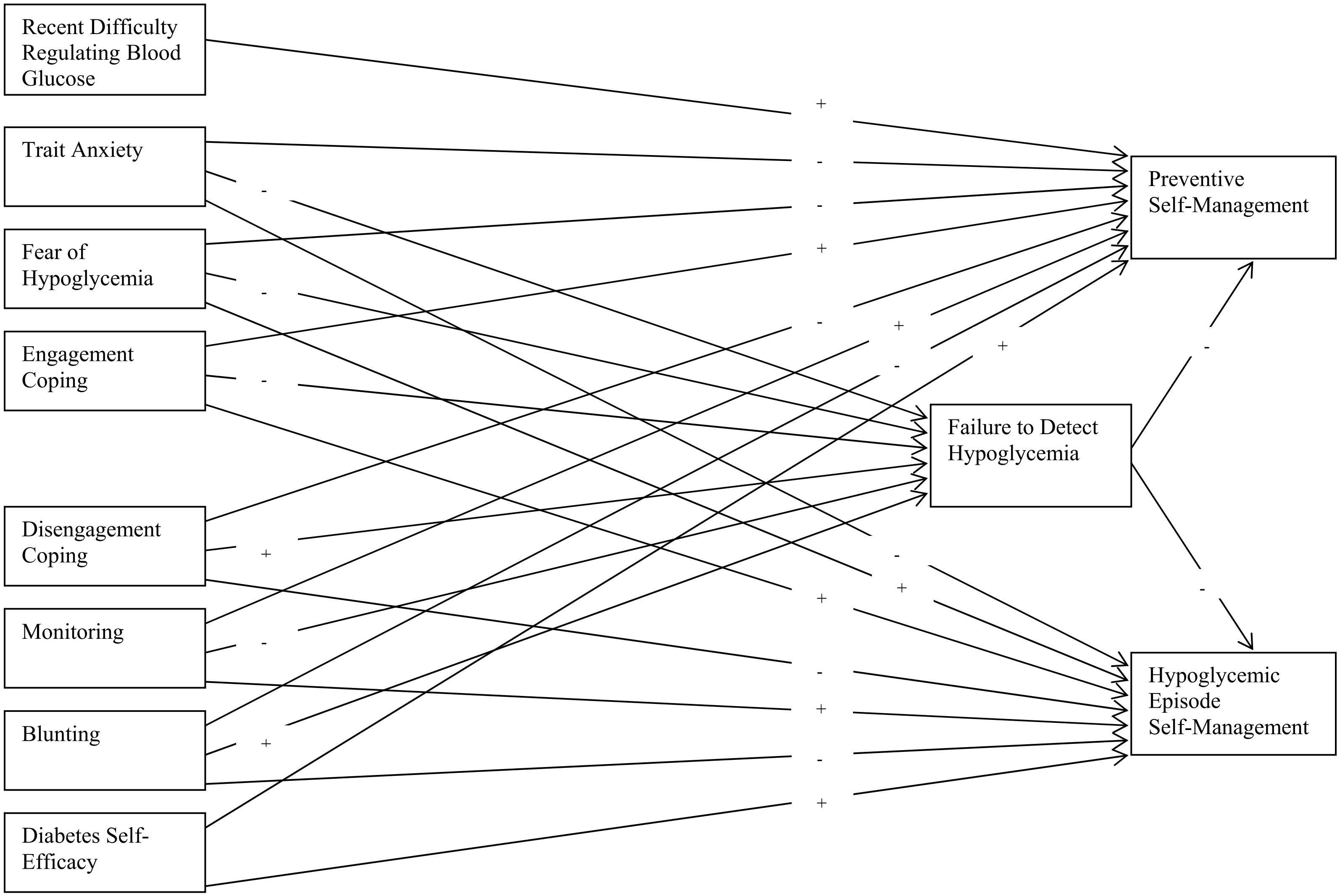

Figure 2. Predicted relationships for the proposed model with the mediating error of failure to detect hypoglycemia.

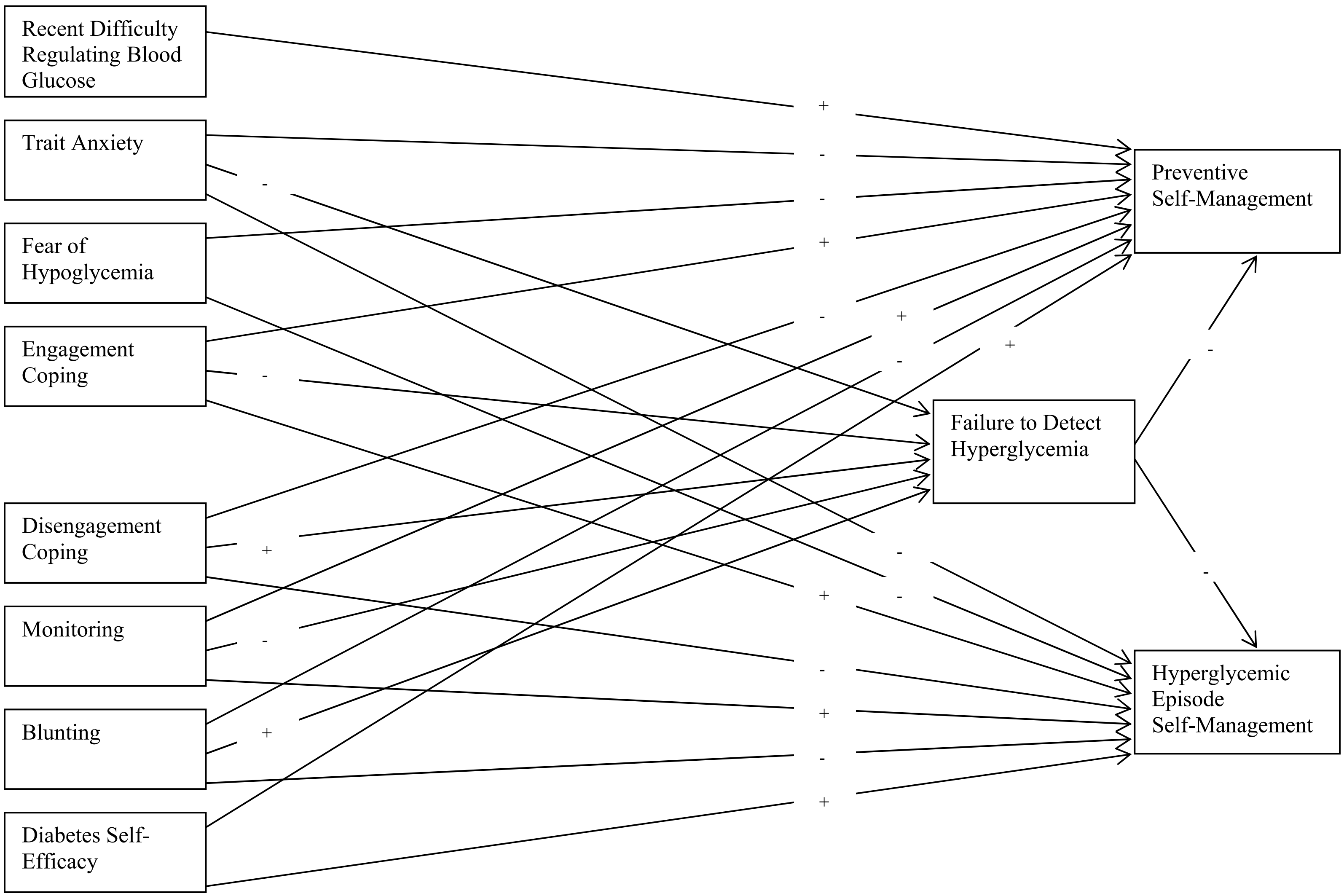

Figure 3. Predicted relationships for the proposed model with the mediating error of failure to detect hyperglycemia.

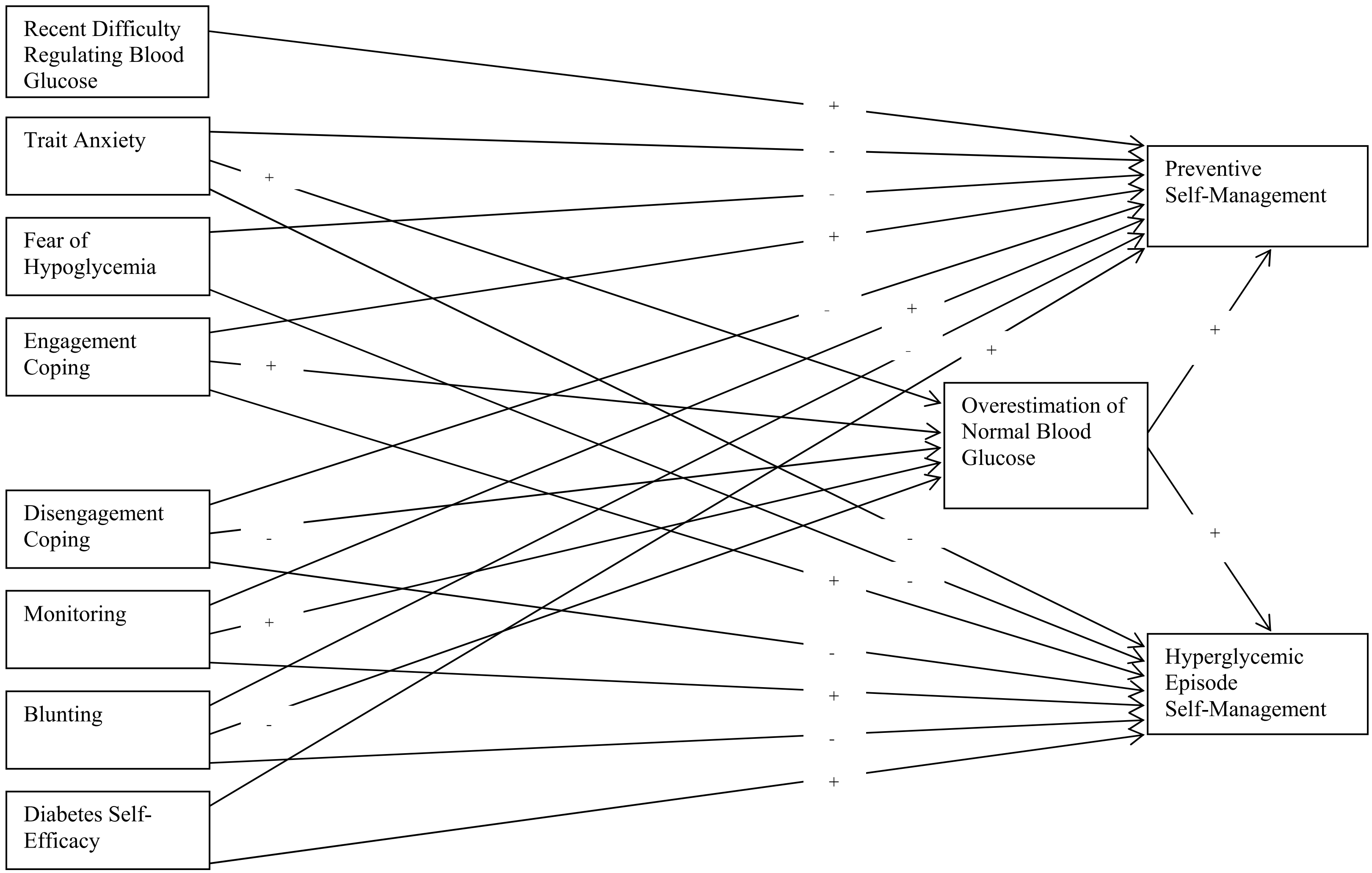

Figure 4. Predicted relationships for the proposed model with the mediating error of overestimation of normal blood glucose.

3. Failure to detect hypoglycemia will relate directly to both preventive and hypoglycemic episode self-management behaviors such that increased failure to detect hypoglycemia will be related to decreased preventive and hypoglycemic episode self-management behaviors.
4. Failure to detect hypoglycemia will mediate the relationship between the exogenous variables and both preventive and hypoglycemic episode self-management behaviors.

Hypotheses for failure to detect hyperglycemia (see Figure 3):

1. Disengagement coping and blunting will be related to increased failure to detect hyperglycemia, whereas trait anxiety, engagement coping, and monitoring will relate to reduced detection failure. Recent difficulty regulating blood glucose and diabetes self-efficacy will not relate to failure to detect hyperglycemia.
2. Engagement coping, monitoring, and diabetes self-efficacy will be related to increased hyperglycemic episode self-management behavior, whereas trait anxiety, fear of hypoglycemia, disengagement coping, and blunting will be related to decreased hyperglycemic self-management behavior. Recent difficulty regulating blood glucose will not relate to hyperglycemic episode self-management.
3. Failure to detect hyperglycemia will directly relate to both preventive and hyperglycemic episode self-management behaviors such that increased failure to detect hyperglycemia will relate to decreased preventive and hyperglycemic episode self-management behaviors.

4. Failure to detect hyperglycemia will mediate the relationship between the exogenous variables and both preventive and hyperglycemic episode self-management behaviors.

Hypotheses for over-estimation of normal blood glucose likely to lead to over-corrective treatment (see Figure 4):

1. Trait anxiety, engagement coping, and monitoring will be related to increased overestimation of normal blood glucose whereas disengagement coping and blunting will be related to decrease in such overestimations. Recent difficulty regulating blood glucose, fear of hypoglycemia, and diabetes self-efficacy will not relate to overestimation of normal blood glucose.
2. Relationships among exogenous variables and hyperglycemic episode self-management behavior were outlined above in hypothesis two for the failure to detect hyperglycemia model.
3. Overestimation of normal blood glucose will directly relate to preventive self-management behaviors and hyperglycemia self-management behaviors such that increased overestimation will be related to increased preventive and hyperglycemia episode self-management behaviors.
4. Overestimation of normal blood glucose will mediate the relationship between the exogenous variables and both preventive and hyperglycemic episode self-management behaviors.

METHOD

Participants

Participants included 169 children or adolescents between the ages of 10 and 16 years who were diagnosed with diabetes and were attending a summer camp designed for children with diabetes. One parent of each child or adolescent also participated. Participant recruitment occurred through four summer camp sessions for children with diabetes in the states of Texas and Oklahoma. Table 2 includes demographic characteristics of the sample. Information to calculate participation rate was only available for Texas Lion's Camp. For both camp sessions 1 and 2 combined, 31% of eligible children participated. Non-respondent data could not be collected, and it is therefore unclear whether or not participants differed from non-respondents on demographic or illness-related variables. It is important to note that children attending Camp Sandcastle were notably younger than at the other camps, reducing the number of eligible children and thereby accounting for the small number of participants from that camp.

Procedure

Participant recruitment and parent data collection. Camp registration materials included a letter inviting parents to participate. Parents completed a demographic questionnaire and a child medical history information form at the time of consent and returned them to the research team by mail. The additional parent instrument packet was completed either at a parent orientation meeting, when the parent dropped his or her child off at camp, or by mail.

Table 2

Sample Demographics

Demographic variable	Total sample (*N* = 169)
Camp attended	
Camp Sandcastle	8 (4.73)
Texas Lions Camp Session 1	63 (37.28)
Texas Lions Camp Session 2	47 (27.81)
Camp Endres	51 (30.18)
Age in years	
M (*SD*)	12.44 (1.64)
Range	10-16
Sex	
Males	77 (45.56)
Females	91 (53.85)
Unknown	1 (0.59)
Ethnicity	
African-American	9 (5.33)
American Indian or Alaska Native	7 (4.14)
Biracial	9 (5.33)
Hispanic	12 (7.10)
White	122 (72.19)
Other	2 (1.18)
Unknown	8 (4.73)
Parent marital status	
Married	119 (70.41)
Separated/Divorced	34 (20.12)
Single	7 (4.14)
Widowed	3 (1.78)
Unknown	6 (3.55)
Method of insulin administration	
Injection	102 (60.36)
Insulin Pump	66 (39.05)
Unknown	1 (0.59)

Note. Values in parentheses reflect percentages unless otherwise specified.

Child and adolescent data collection. On the first day of camp, children and adolescents of consenting parents completed questionnaires during supervised group administration. Collection of perceptual accuracy data occurred using standard procedures at the time of each participant's regularly scheduled blood glucose checks, up to four times per day throughout the camp session. Each participant predicted his or her blood glucose immediately prior to testing it, and a research assistant recorded observed blood glucose. The blood glucose test typically consists of pricking the finger to obtain a small drop of blood, placing it on a test strip, and observing the numerical reading provided by the meter. Undergraduate students from Texas A&M University served as camp counselors, assisted with collection of questionnaire data, and collected the perceptual accuracy data.

Measures

Demographic information. Consenting parents completed a brief demographic questionnaire including basic demographic information about the participating child and parent.

Child medical history information. Participating parents also completed a brief child medical history questionnaire including type of diabetes, month and year of diagnosis, presence of any other chronic health condition, history of diabetes related medical problems, morbidity variables for the past year, and information about all medications (including insulin) prescribed for diabetes in the past year.

Prediction of blood glucose. Prior to each blood glucose check included in the study, participants provided a prediction of blood glucose level by completing the Blood

Glucose Prediction Scale. Designed for this study, the scale consists of a vertically oriented Visual Analogue Scale (VAS) ranging from 0 to 400 mg/dl. Each participant marked a line indicating the value of the predicted or expected blood glucose measurement.

Objective measure of current blood glucose. Blood glucose testing meters were used to give a single blood glucose reading at each time of measurement. These measurements occurred up to four times per day for each day of camp.

Self-management behaviors. The Diabetes Self-Management Questionnaire (DSMQ), a child/adolescent report and parent report questionnaire designed for this study, was used to assess the frequency with which participants reportedly engaged in diabetes-specific self-management behaviors. The measure was not designed to account for differences in method of insulin administration (i.e., injection vs. pump), and only those items pertaining to both methods of administration were retained. The resulting Diabetes Self-Management Questionnaire-Child Form (DSMQ-C) included four parts: (a) 13 items assessing diabetes-related self-care behaviors occurring in the past three days, (b) 13 items assessing acute self-management behavior occurring during the last hypoglycemic episode, (c) 15 items assessing acute self-management during the last hyperglycemic episode, and (d) 3 items measuring perceived degree of difficulty regulating blood glucose for the past three days. The Diabetes Self-Management Questionnaire Parent-Form has four analogous parts but assesses parent-report of child behaviors over the past month.

Generation of items followed a review of typical components to the diabetes treatment regimen as well as available measures for assessing diabetes self-management (Glasgow, McCaul, & Schafer, 1987; Johnson, Silverstein, Rosenbloom, Carter, & Cunningham, 1986; Marquis, Ware, & Relles, 1979; McNabb, Quinn, Murphy, Thorp, & Cook, 1994; Reid, Dubow, Carey, & Dura, 1994; Toobert & Glasgow, 1994). Independently, these measures were primarily limited by insufficient in breadth with regard to types of self-management behaviors, developmental inappropriateness for use with children and adolescents, and/or restriction to parent report. Johnson's 24-hour recall interview (Johnson et al., 1986) is the "gold standard" in the assessment of diabetes self-management, but interview format was not possible for the group administration design.

Trait anxiety. The State-Trait Anxiety Inventory for Children (STAIC; Spielberger, 1973) assessed trait anxiety. The STAIC is a 40-item questionnaire on a four-point Likert scale designed for children ages 9 to 12 years and normed on children from the 4^{th} to 6^{th} grade. The 20-item trait scale used in this study assessed the degree to which a child has an anxious disposition or tendency toward anxious symptomatology. Research has supported the internal consistency, test retest reliability, concurrent validity, and construct validity of the measure (Spielberger, 1973).

Fear of hypoglycemia. The Worry subscale of the Hypoglycemia Fear Survey-II-R (HFS-II-R; Irvine, Cox, & Gonder-Fredrick, 1994) measured fear of hypoglycemia. The HFS-II-R Worry Scale is a 16-item questionnaire designed to assess the degree to which the respondent worries about experiencing a series of consequences related to low blood glucose level. Development of the scale used a sample of IDDM patients from age 15 to 80 years, and research has supported the internal consistency, test retest reliability, concurrent validity, and discriminant validity of the Worry subscale (Irvine et al., 1994).

Coping style. A modified version of the Coping Strategies Inventory (CSI; Tobin, Holroyd, & Reynolds, 1984; Tobin, Holroyd, Reynolds, & Wigal, 1989) measured diabetes-specific coping behaviors. In the original CSI, respondents self-identify a recent stressful event and then respond to 72 items by rating the degree to which they used a variety of coping strategies using a five-point Likert scale. For this study, a diabetes-specific prompt was given to participants (i.e., "please mark…how much you did each of these things to help yourself the last time you had trouble with your blood sugar"). Nine items that did not appear relevant to diabetes-specific, more acute situations were omitted. Internal consistency, test retest reliability, and convergent validity of the original measure have been supported (Tobin et al., 1984; Tobin et al., 1989). This study used the two tertiary factors of Engagement Coping and Disengagement Coping.

Attentional style. Measurement of attentional style included questions modified from the Miller Behavioral Style Scale (MBSS; Miller, 1987), the Child Behavioral Style Scale (CBSS; Miller et al., 1995), and included an added diabetes-specific scenario. The MBSS and the CBSS measure attentional style in stressful situations, specifically the dispositional tendency to engage in information-seeking strategies (monitoring) and information-avoiding or distracting strategies (blunting). The scale asks respondents to imagine stress-evoking scenes and to indicate which of a list of attentional strategies they would use for dealing with each situation. Summing the responses to these items yields two scores, a total monitoring score and a total blunting score (Miller, 1987). Internal consistency of the MBSS has ranged from .70 to .80 and for the CBSS from .62 to .65 (Miller, Rodoletz, et al., 1996; Miller et al., 1995).

The modified scale used in this study included three scenarios: the doctor's office and dentist's office scenarios taken from the CBSS, and a diabetes-specific scenario. The first two scenarios include the original CBSS response options, but some items were slightly modified to make them more general or appropriate for adolescents (e.g., "Play with toys or a game in the waiting room" was changed to "Play with toys or look at something to distract yourself"). Three items from the MBSS that were modified for more child-appropriate wording were also added to the dentist office scenario. For the diabetes specific scenario, the respondent received the prompt: "Imagine that you are doing something that you think might make your blood sugar out of balance, either too low or too high." Response options included six monitoring strategies (e.g., "Pay attention to how your stomach or head feels") and five blunting strategies (e.g., “Avoid thinking about your blood sugar").

Self-efficacy. The Self-Efficacy for Diabetes Scale (SEDS; Grossman Brink, & Hauser, 1987) consists of 35 items constructed to evaluate children and adolescents' perceptions of their personal ability to manage diabetes related situations. It consists of three conceptually derived subscales: SED-Diabetes Specific (24 items), SED-Medical Situations (five items), and SED-General Situations (six items). For the original measure, respondents rate degree of confidence in their ability to engage in each stated behavior using a six-point Likert scale, but this study used a five-point Likert scale to promote consistency across measures. This study used the SED-Diabetes Specific subscale, eliminating one item specifying insulin administration by injection and adding three items to measure self-efficacy for symptom perception (e.g., I can tell by how I feel if my blood sugar is too low"). Previous research cited the Kuder-Richardson coefficient for the SED-Diabetes Specific subscale to be .92, and the SED total score has demonstrated convergent validity (Grossman et al., 1987).

Responsibility for disease management. The Diabetes Management Responsibility Questionnaire (DMRQ), designed for this study, measured the degree to which the participating child or adolescent reported being responsible for engaging in self-management behaviors. Both parent and child forms are 26-item, five-point Likert scale questionnaires assessing the relative degree to which the parent or child has responsibility for a variety of diabetes regimen tasks. Development of this questionnaire followed review of two existing scales of regimen responsibility for diabetes: the Diabetes Regimen Responsibility Scale (Ruggiero, Mindell, & Kairys, 1991), which was cumbersome in format, and the Diabetes Family Responsibility Questionnaire (Anderson, Auslander, Jung, Miller, & Santiago, 1990), which was less comprehensive than desired. Item generation followed the content of these two scales.

Blood glucose threshold for treatment. To determine at what level of physiological functioning each participant reportedly would take corrective self-management action, each participant estimated the blood sugar reading that would bring him or her to take action about hypo- and hyperglycemia.

RESULTS

Scale Reliability

Chronbach's alpha and item total correlations assessed internal consistency reliability for all measures (see Table 3). Internal consistency was excellent for the measures of trait anxiety, fear of hypoglycemia, coping, diabetes self-efficacy, and diabetes management responsibility. It was acceptable for the hyperglycemic episode self-management and attentional style measures and was questionable for the preventive and hypoglycemic episode self-management measures.

Principal Components Analysis of the Diabetes Self-Management Questionnaire - Child Form

A principal components analysis of the preventive items of the DSMQ-C using an oblique (i.e., oblimin) rotation determined components into which the items emerged. Examination of the appropriateness of the data for factor analysis indicated that the measure of sampling adequacy (MSA) was “middling” (overall MSA = .75; Kaiser, 1981). Because the individual item MSA for item 10 (Change your insulin dose or schedule because you should have) was below .6 (“unacceptable”; Kaiser, 1981), this item was deleted, increasing the overall MSA to .77. With the remaining items, four factors had eigenvalues greater than one, but the scree plot (see Figure 5) and the original factor solution indicated that retaining two factors was most appropriate. Examining item content yielded these components: (a) Blood Glucose Regulation and (b) Prevention of Diabetes-Related Problems (see Table 4 for factor loadings). Combined, these two components accounted for 40.21% of the variance.

Table 3

Scale Reliability Indices

Measure	Chronbach's alpha	Range of item total correlations
Diabetes Self-Management Questionnaire – Child Form (DSMQ-C) Preventive Management	.67	.20-.51
DSMQ-C Hypoglycemic Episode Self-Management	.69	.05-.48
DSMQ-C Hyperglycemic Episode Self-Management	.75	.13-.48
State-Trait Anxiety Inventory for Children – Trait Scale	.90	.33-.64
Hypoglycemia Fear Survey-II-R Worry Scale	.91	.52-.72
Copying Strategies Inventory – Diabetes Form	.95	.19-.66
Child Behavioral Style Scale – Modified	.79	.02-.47
Self-Efficacy for Diabetes Scale – Diabetes Specific	.96	.33-.82
Diabetes Management Responsibility Questionnaire – Child Form	.97	.64-.82

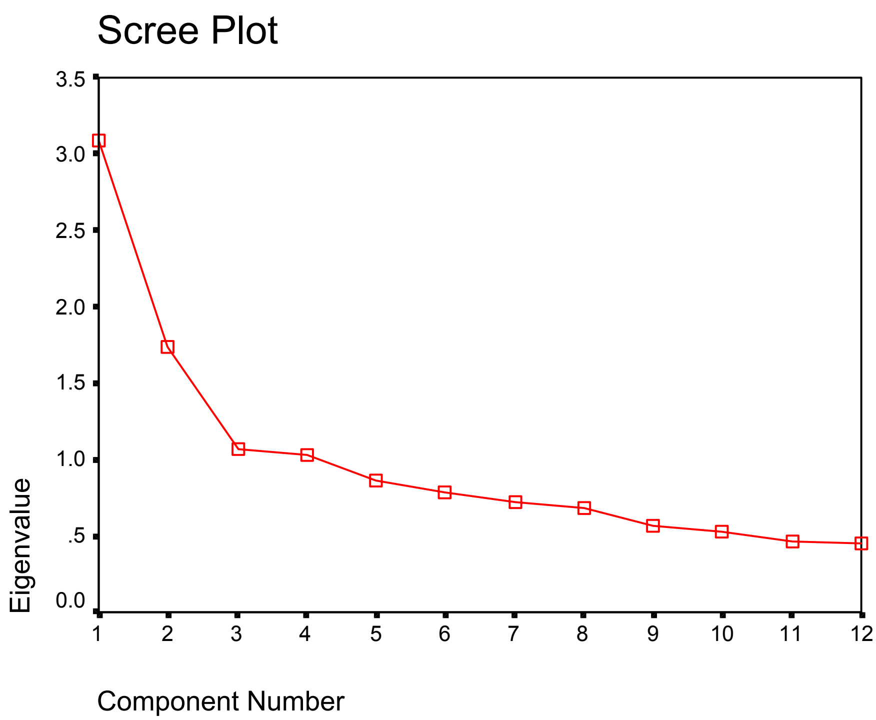

Figure 5. Scree plot for the principal components analysis of the Diabetes Self-Management Questionnaire-Child Form preventive items using an oblimin rotation.

Table 4

Structure Matrix Factor Loadings from the Principal Components Analysis and Oblimin Rotation of the Diabetes Self-Management Questionnaire-Child Form Preventive Management Items

Items	Factor 1 Loadings	Factor 2 Loadings
Factor 1 (eigenvalue = 3.04)		
Wear shoes that fit well	.49	.18
Test your blood sugar at the right time in relation to meals	.69	.17
Eat or drink something that you're not supposed to*	.54	-.04
Measure your insulin doses correctly	.69	-.11
Take an injection or use your pump when you knew you should	.66	.13
Take your insulin at the right times in relation to meals	.76	.20
Exercise or do something active	.65	.02
Factor 2 (eigenvalue = 1.86)		
Carry something with you that had sugar in it	.04	.59
Measure or weigh the amount of food you ate	.01	.61
Carry or wear something that says you're diabetic	.29	.53
Change your eating time because you should have (e.g., exercise)	-.06	.60
Check your feet for signs of problems	.17	.61

Note. Factor 1 = Blood Glucose Regulation; Factor 2 = Prevention of Diabetes-Related Problems.

* item was reverse scored

Independently, the Blood Glucose Regulation factor accounted for 25.33% of the variance and the Prevention of Diabetes-Related Problems factor accounted for 15.51%. Because the rotation was oblique, some of this variance is shared and thus the two independent estimates of variance sum to a slightly higher value than the cumulative percentage. The correlation between these two components was .12.

Although the sample size is relatively small, the factor loadings indicate that these components are likely to be stable. According to Guadagnoli and Velicier (1988), a component with four or more loadings above .60 in absolute value is reliable, regardless of sample size. The Blood Glucose Regulation factor has five loadings above .60, and the Prevention of Diabetes-Related Problems factor has three loadings at or above .60 and another at .59, evidence for their reliability.

Perceptual Accuracy and Estimation Errors

Error grid analysis. Error grid analysis quantified perceptual accuracy and perceptual errors. Cox and colleagues developed this method (Cox et al., 1985; Cox et al., 1989) for use with patients with diabetes. In general, error grid analysis includes plotting estimated blood glucose by observed blood glucose for multiple times of measurement, yielding one error grid per participant with multiple data points. Observing the clinically meaningful zone in which these plots fall provides a measure of the frequency of clinically accurate estimates as well as the frequency of a variety of clinically important errors.

Figure 6 depicts the error grid. The center diagonal line reflects perfect estimated-observed agreement, with plots above the diagonal representing overestimates and plots below it representing underestimates. Participant estimates are defined as accurate if they fall in the A Zone, which includes estimates that are within 20% of the observed value or that represent hypoglycemic estimates (<70 mg/dl) when observed blood glucose is also hypoglycemic. B zones include inaccurate estimates (either over- or underestimation of blood glucose) that would lead to clinically benign self-management decisions. Plots in C zones reflect estimates that would lead to potentially dangerous self-management decisions to overcorrect an acceptable blood glucose level. D zones reflect dangerous failures to detect extreme blood glucose levels (<70 or >180 mg/dl), and E zones reflect estimates in which hypoglycemia is confused for hyperglycemia and vice versa. An accuracy index (AI) is computed by subtracting the summed percentage of clinically significant errors from the summed percentage of accurate estimates and ranges from -100 to 100. Positive AI scores reflect higher frequency of clinically accurate estimates compared with clinically serious errors, whereas negative AI scores indicate more errors than accurate estimates (Cox et al., 1989). Figures 7, 8, and 9 present error grids for three participants in the study.

Multiple indices of perceptual accuracy and estimation errors were calculated for this study. Given the variability in the number of data points given by each participant, participants were required to have a minimum of 10 data points, including a blood glucose measurement and prediction of that measurement. This resulted in exclusion of 11 participants from analyses of perceptual accuracy and a mean of 13.78 observations.

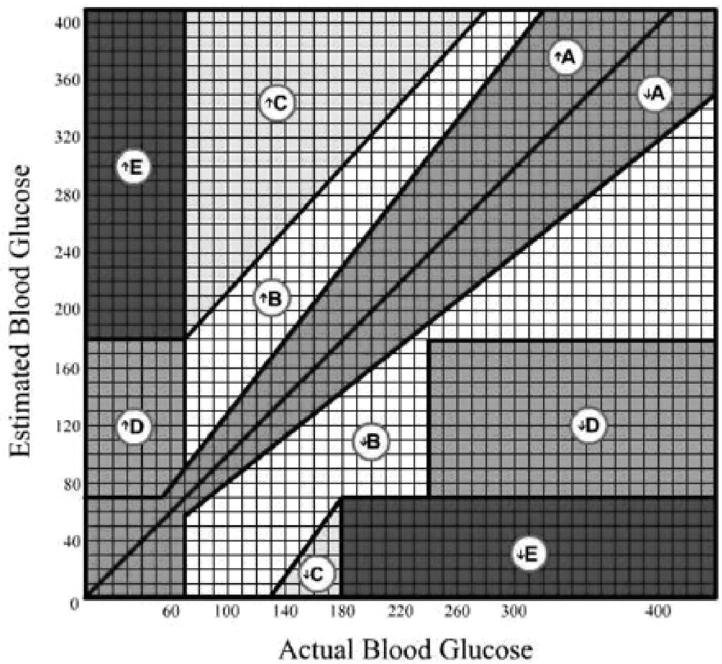

Figure 6. Error grid analysis for evaluating an individual's accuracy of blood glucose estimation. Diagonal line = perfect estimated-observed blood glucose agreement; A Zones = clinically accurate estimates of blood glucose; B Zones = clinically benign errors; Upper C Zone = overestimation of a normal blood glucose likely to lead to over-corrective treatment; Lower Zone C = underestimation of a normal blood glucose likely to lead to over-corrective treatment; Upper D Zone = failure to detect hypoglycemia; Lower D Zone = failure to detect hyperglycemia; Upper E Zone = estimating as hyperglycemic when hypoglycemic; Lower E Zone = estimating as hypoglycemic when hyperglycemic; Accuracy Index = % A Zone – (%C + %D + %E).

Note. From "Blood Glucose Estimations in Adolescents with Type I Diabetes: Predictors of Accuracy and Error," by L. J. Meltzer, S. Bennett-Johnson, S. Pappachan, and J. Silverstein, 2003, *Journal of Pediatric Psychology, 28*, p. 205. Copyright 2003 by the Society of Pediatric Psychology. Reprinted with permission.

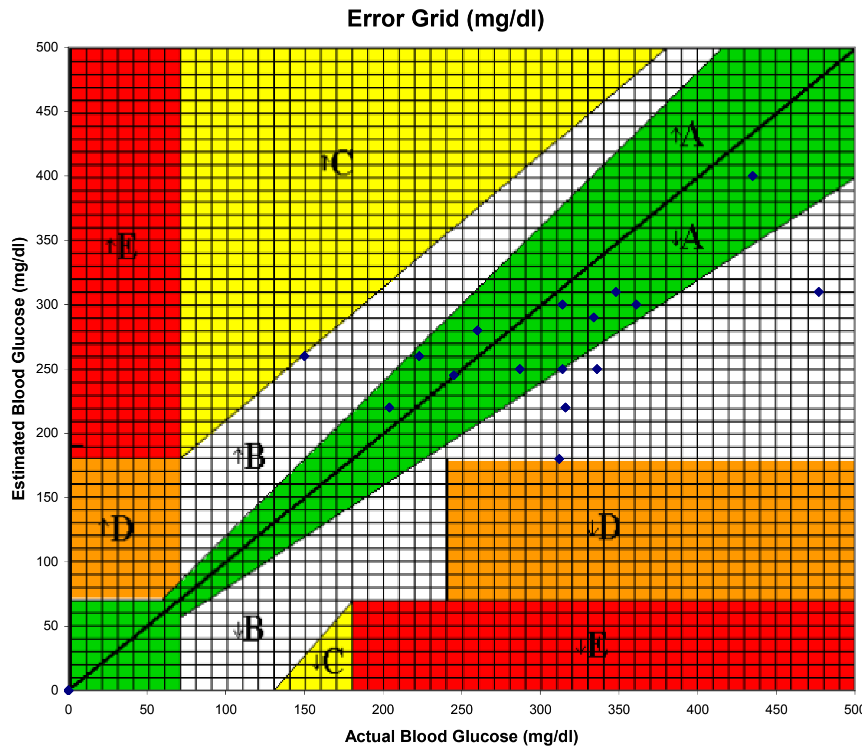

Figure 7. Example error grid from a participant with a positive accuracy index in the present sample. Accuracy Index = 62.50%.

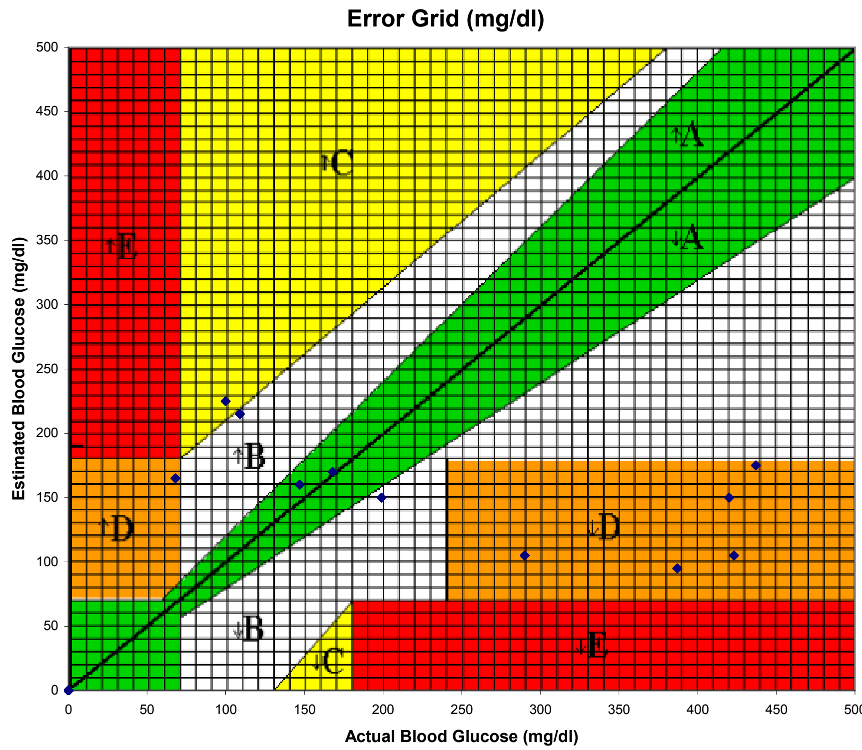

Figure 8. Example error grid from a participant with a negative accuracy index in the present sample. Accuracy Index = -45.50%.

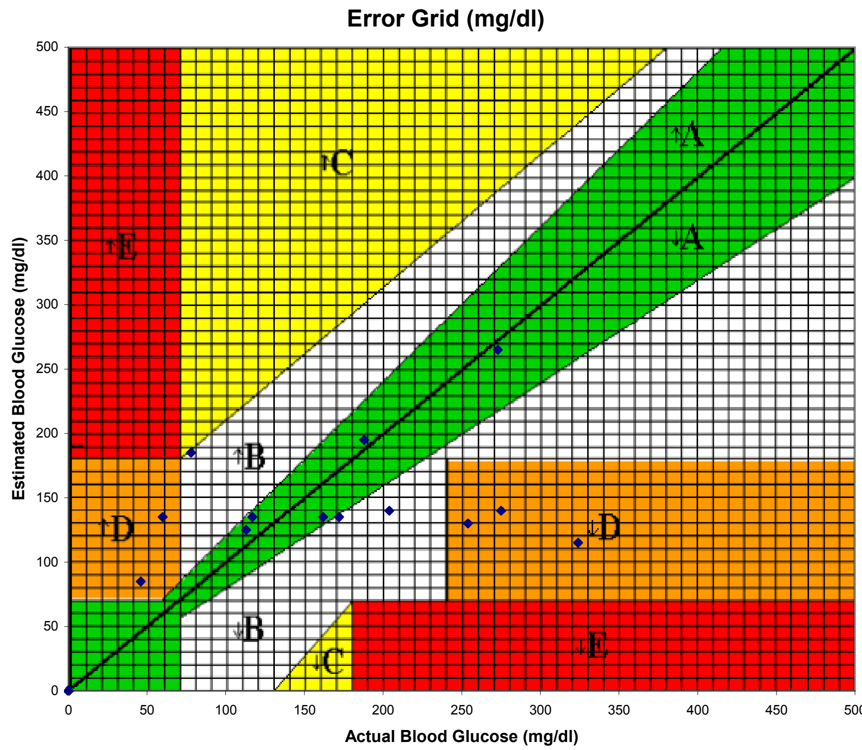

Figure 9. Example error grid from a participant with an accuracy index of zero in the present sample. Accuracy Index = 0.00%.

Quantification of global perceptual accuracy for each participant included (a) an accuracy index from error grid analysis (i.e., total percentage of accurate estimates minus total percentage of clinically dangerous estimates) and (b) correlation between predicted physiological functioning and observed functioning. To quantify specific perceptual errors, a variety of estimation error indices were calculated from the error grid analyses.

The hypoglycemia detection failure index is the percentage of estimates falling in the Upper D Zone. The hyperglycemia detection failure index is the percentage of estimates falling in the Lower D Zone. The index of overestimation of normal blood glucose likely to lead to over-corrective treatment is the percentage of estimates falling in the Upper C Zone. No individuals in the sample made the error of underestimating normal blood glucose such that it would lead to over-corrective treatment (i.e., Lower C Zone); therefore, there was no need to calculate the underestimation of normal blood glucose index or to model this type of perceptual error. The mean percentages of estimates falling into each zone for the sample are in Table 5.

The mean blood glucose level was calculated for each individual participant across perceptual accuracy trials and ranged from 58.81 mg/dl to 324.30 mg/dl with an overall sample mean of 175.48 mg/dl. The standard deviation for individuals' blood glucose levels across trials ranged from 12.25 to 144.78, with an average standard deviation of 79.39. Mean correlations between an individual's predicted blood glucose and his or her observed blood glucose ranged from -.62 to .87. Based on Cohen's (1992) guidelines, approximately 1% of participants had a large negative correlation, 4% a

Table 5

Summary of Percentage of Estimates in Error Grid Analysis Zones (N = 148)

	Sample Mean	Standard Deviation	Range
Overall Accuracy Index	14.73	27.06	-64.30 – 81.30
Clinically Relevant Errors	20.36	14.74	0.00 – 64.30
A Zone	34.65	16.43	0.00 – 81.30
Upper A Zone	14.50	10.47	0.00 – 45.50
Lower A Zone	20.14	12.37	0.00 – 68.80
B Zone	44.25	14.74	6.30 – 78.50
Upper B Zone	18.95	12.34	0.00 – 57.10
Lower B Zone	25.28	13.33	0.00 – 63.60
C Zone	2.84	5.26	0.00 – 27.30
Upper C Zone	2.84	5.26	0.00 – 27.30
Lower C Zone	0.00	0.00	0.00
D Zone	15.61	13.38	0.00 – 57.20
Upper D Zone	4.68	7.61	0.00 – 45.50
Lower D Zone	10.93	11.52	0.00 – 50.00
E Zone	1.90	4.61	0.00 – 27.30
Upper E Zone	1.11	3.67	0.00 – 27.30
Lower E Zone	0.79	2.97	0.00 – 27.30

Note. Upper and Lower A Zones = clinically accurate estimate of blood glucose; Upper B Zone = clinically benign overestimation of blood glucose; Lower B Zone = clinically benign underestimation of blood glucose; Upper C Zone = overestimation of normal blood glucose likely to lead to over-corrective treatment; Lower C Zone = underestimation of normal blood glucose likely to lead to over-corrective treatment; Upper D Zone = failure to detect hypoglycemia; Lower D Zone = failure to detect hyperglycemia; Upper E Zone = erroneous estimation of hyperglycemia when hypoglycemic; Lower E Zone = erroneous estimation of hypoglycemia when hyperglycemic.

medium negative correlation, 11% a small negative correlation, 14% no meaningful correlation, 16% a small positive correlation, 17% a medium positive correlation, and 37% a large positive correlation. Fisher's *r* to *z* transformation was used to compute the mean correlation for the sample, such that each participant's *r* value was converted to a *z* value, the mean was computed, and the mean *z* value was then back transformed to the *r* value ($r = .35$).

The accuracy index was positively correlated with participant age ($r = .26$, $p = .001$; small to medium effect size), reflecting increasing accuracy with increasing age. Accuracy was not significantly correlated with illness duration ($r = -.02$, $p = .83$). *T*-tests explored the possibility of differences in perceptual accuracy for gender and method of insulin administration (i.e., pump vs. injection). The mean accuracy index for girls was higher than for boys (18.33% vs. 10.08%, respectively); the difference was not statistically significant, $t(143) = -1.90$, $p = .06$, and the effect size was small to medium ($d = .32$). Concerning insulin administration, the accuracy index was normally distributed for both groups, but Levene's test for equality of variances was significant, $F(1, 145) = 4.71$, $p = .03$, so the t-value not assuming equal variances was examined. No significant differences for method of insulin administration existed for the perceptual accuracy index, $t(137) = -.75$, $p = .46$, and the effect size was very small ($d = .12$).

Perceptual Accuracy and Practice Effects

A dependent-samples *t*-test assessed for practice effects on perceptual accuracy (i.e., change in the accuracy index as the difference between each participant's accuracy index for the first sequential half of blood glucose estimates and the second half of estimates). Although the mean accuracy index for the second half of estimates (16.10%) was higher then the first half (12.53%), this difference was not statistically significant, $t(146) = -1.09$, $p = .28$, and the effect size was very small ($d = .11$). A one-way analysis of variance (ANOVA) also determined if camps differed according to practice effects. Results reflected no significant differences between camps, $F(3, 143) = .34$, $p = .81$, and the effect size was small ($\eta^2 = .01$).

Relationships Between Age, Illness Duration, and Model Variables

Inspection of simple correlations yielded information about the independent relationships between both age and illness duration and the model variables and are reported in Table 6.

Two multivariate regression analyses tested if the continuous variables of age and illness duration predicted the path model variables in combination. For the independent variable of age, Wilk's Λ (.71) was statistically significant, $F(14, 116) = 3.39$, $p < .001$, indicating that age did significantly predict some combination of the dependent variables. The correlation between age and the canonical variable was .54, and the effect size was large ($\eta^2 = .29$). Examination of the standardized canonical coefficients and structure coefficients indicated that the primary variable contributing to the effect was failure to detect hyperglycemia; as age increased the tendency to make this error decreased. However, failure to detect hypoglycemia and diabetes self-efficacy also contributed to the effect, with increasing age relating to increases in both of those variables.

Table 6

Correlations Between Age, Illness Duration, and Path Model Variables

	Participant Age in Years	Illness Duration
Recent Difficulty Regulating Blood Glucose	.03	-.04
Trait Anxiety	-.04	.09
Fear of Hypoglycemia	.01	.08
Engagement Coping	-.08	.06
Disengagement Coping	.01	.07
Monitoring	-.10	-.12
Blunting	-.06	.14
Diabetes Self-Efficacy	.18*	-.06
Failure to Detect Hypoglycemia	.19*	.06
Failure to Detect Hyperglycemia	-.39**	.06
Overestimation of Blood Glucose	-.13	.00
Preventive Self-Management	.00	-.08
Hypoglycemia Self-Management	-.06	-.09
Hyperglycemia Self-Management	.10	.02

*$p < .05$
**$p<.001$

For illness duration, Wilk's Λ (.92) was not statistically significant, $F(14, 111) = .72$, $p = .75$. The correlation between illness duration and the canonical variable was .29, and the effect size was medium ($\eta^2 = .08$). Because the multivariate test was not statistically significant, standardized canonical coefficients and structure coefficients could not be examined.

Relationships Between Model Variables and the Potential Confound of Camp Attended

Examination of the Box's M test of the homogeneity of variance-covariance matrices from a one-way multivariate analysis of variance (MANOVA) assessed if the variables in the model were differentially related according to camp attended (i.e, Camp Sandcastle, Lions Camp Session 1, Lions Camp Session 2, or Camp Endres). The Box's M test was statistically significant, Box's M = 346.13, $F(210, 21223) = 1.34$, $p = .001$, indicating that the homogeneity of variance-covariance matrices assumption had been violated either due to different variances or covariances. Examination of simple correlations for each camp reflected some notable differences in correlations (including between Lions Camp Session 1 and Lions Camp Session 2), suggesting that the model variables did relate differently according to camp. Such results might warrant conducting separate path analyses for each camp group; however, doing so would result in insufficient sample size. Because of this limitation and because no theoretical reason existed for camp differences, the path models were conducted on the total sample.

Path Analyses of the Proposed Models

Path analysis, conducted with LISREL 8.51 using the maximum likelihood estimation method, assessed the hypotheses based on the model presented in this paper.

Three models were estimated, each based on a specific type of estimation error that serves as a mediator in the model: (a) failure to detect hypoglycemia, (b) failure to detect hyperglycemia, and (c) overestimation of normal blood glucose likely to lead to over-corrective treatment. The model of underestimation of normal blood glucose likely to lead to over-corrective treatment could not be estimated because no participants made that error in this sample. For each of these models, the exogenous variables included recent difficulty regulating blood glucose, trait anxiety, fear of hypoglycemia, engagement coping, disengagement coping, monitoring, blunting, and diabetes self-efficacy. The model-specific perceptual error served as the mediating variable between these exogenous variables and the endogenous variables of preventive self-management behavior and acute self-management behavior (i.e., either hypoglycemic episode self-management or hyperglycemic episode self-management).

Examination of the χ^2 statistic and goodness-of-fit indices [i.e., Root Mean Square Error of Approximation (RMSEA), Normed Fit Index (NFI), Non-Normed Fit Index (NNFI), Comparative Fit Index (CFI), Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Parsimony Normed Fit Index (PNFI), and Parsimony Goodness of Fit Index (PGFI)] evaluated overall fit of each model. The χ^2 statistic tests congruence between the observed correlation matrix and the matrix specified in by the model, a non-significant χ^2 reflecting good fit. The critical *N* is the sample size at which the χ^2 would become significant, and a critical *N* over 200 is desired.

GFI and AGFI compare the observed correlation matrix with the matrix specified in accordance with the model. NFI, NNFI, and CFI compare the fit of the model with the fit of the independence model, when variable relationships are constrained to zero. RMSEA partially accounts for model complexity by taking into account the degrees of freedom in the model, whereas PGFI and PNFI multiply GFI and NFI by the ratio of degrees of freedom in the researcher's model and the independence model. For the RMSEA index, a smaller value reflects better fit, with a value of .06 or less reflecting good model fit (Hu & Bentler, 1999). For the remainder of the fit indices, a larger value reflects closer fit. Most recommendations indicate that for these indices a value of .9 or above reflects sufficient fit of the data with the model, although the degree to which a value of .9 reflects "good" fit vs. "acceptable" fit is a matter of debate (Pedhazur, 1997).

Modification indices, which reflect the reduction in χ^2 that would occur if a path fixed to zero was allowed to be free, were also examined to assess for improvements that could be made to model fit. A modification index of 3.84 or greater, the critical value for a χ^2 with one degree of freedom, was used as the cutoff that suggests modification may be warranted. Assessment of mediational hypotheses predicted by the model included comparing values for total effects and indirect effects; a small, non-significant indirect effect indicates that there is not an indirect effect beyond the direct effect.

Table 7 includes means and standard deviations for all model variables, except for the estimation errors presented in Table 5, and Table 8 presents intercorrelations.

Path analysis concerning failure to detect hypoglycemia. The χ^2 was not statistically significant, χ^2 (4, N = 132) = 5.62, p = .23, indicating a good model fit. Additional goodness-of- fit indices similarly reflected a good fit of the data with this model except for the parsimony fit indices, which account for lack of restrictiveness in

Table 7

Means and Standard Deviations of Path Model Variables

	Sample Mean	Standard Deviation
Recent Difficulty Regulating Blood Glucose	5.79	2.05
Trait Anxiety	32.02	7.75
Fear of Hypoglycemia	29.95	12.07
Engagement Coping	77.23	21.06
Disengagement Coping	78.83	26.65
Monitoring	9.35	3.28
Blunting	6.89	3.44
Diabetes Self-Efficacy	101.44	23.41
Preventive Self-Management	46.95	6.80
Hypoglycemia Self-Management	11.36	1.93
Hyperglycemia Self-Management	12.51	2.53

Table 8

Correlations Among Path Model Variables

	DRBG	TA	FH	EC	DC	M	B	DSE	FDHo	FDHr	ONBG	PSM	HoSM	HrSM
DRBG	-													
TA	.15	-												
FH	.03	.39**	-											
EC	-.13	.09	.12	-										
DC	.12	.41**	.28**	.61**	-									
M	-.02	.13	.13	.21*	.14	-								
B	-.04	.16	.02	.20*	.18*	.25**	-							
DSE	.04	-.21*	-.05	.07	-.05	-.02	-.10	-						
FDHo	-.05	-.16	-.01	-.02	-.07	-.12	-.11	-.04	-					
FDHr	-.00	.01	-.04	.10	.05	.01	.26**	-.06	-.07	-				
ONBG	.18*	.11	.05	-.10	-.07	-.06	-.01	.05	-.06	.03	-			
PSM	-.19*	-.21*	.10	.18*	.02	-.03	-.10	.35**	-.12	.05	.08	-		
HoSM	-.10	-.20*	.06	-.05	-.27**	.11	-.07	.27**	.01	.04	.11	.32**	-	
HrSM	-.06	-.21*	.11	-.07	-.24**	.04	-.15	.25**	.06	-.06	.06	.27**	.62**	-

* p < .05
** p < .01

Note. DRGB = recent difficulty regulating blood glucose, TA = trait anxiety, FH = fear of hypoglycemia; EC = engagement coping; DC = disengagement coping; M = monitoring; B = blunting; DSE = diabetes self-efficacy; FDHo = failure to detect hypoglycemia; FDHr = failure to detect hyperglycemia; ONBG = overestimation of normal blood glucose; PSM = preventive self-management; HoSM = hypoglycemic episode self-management; HrSM = hyperglycemic episode self-management.

the model (i.e., number of paths allowed vs. fixed to zero; see Table 9). No modification indices exceeded 3.84. Modification indices for γ (i.e., for the paths from the exogenous variables to the endogenous variables) also supported that no direct paths were needed between diabetes self-efficacy or recent difficulty regulating blood glucose and failure to detect hypoglycemia, and no direct path was needed between difficulty regulating blood glucose and hypoglycemic episode self-management. However, the exogenous variables explained only 5% of the variance in failure to detect hypoglycemia. The variables affecting preventive self-management behavior accounted for 26% of the variance in combination, and 22% of the variance was accounted for in hypoglycemic episode self-management behavior. Figure 10 provides the standardized path coefficients.

Comparison of values for total effects and indirect effects assessed mediational hypotheses. The model proposes that failure to detect hypoglycemia will mediate the effects of the exogenous variables of trait anxiety, fear of hypoglycemia, engagement coping, disengagement coping, monitoring, and blunting on both the endogenous variables of preventive and hypoglycemic episode self-management behavior. On the contrary, failure to detect hypoglycemia was not a mediator for any of these relationships, with none of the exogenous variables evidencing an indirect effect beyond its direct effect. Examination of specific paths indicated that although some of the exogenous variables had direct effects on management behavior, none of them significantly affected failure to detect hypoglycemia, and failure to detect hypoglycemia did not significantly affect preventive or hypoglycemic episode self-management.

Table 9

Goodness of Fit Indices for Failure to Detect Hypoglycemia Path Analysis (N = 132)

χ^2	*df*	*p*	RMSEA	NFI	NNFI	CFI	GFI	AGFI	PNFI	PGFI	Critical *N*
5.62	4	.23	.06	.98	.88	.99	.99	.87	.07	.06	310.70

Note. RMSEA=Root Mean Square Error of Approximation; NFI=Normed Fit Index; NNFI=Non-Normed Fit Index; CFI=Comparative Fit Index; GFI=Goodness of Fit Index; AGFI=Adjusted Goodness of Fit Index; PNFI=Parsimony Normed Fit Index; PGFI=Parsimony Goodness of Fit Index.

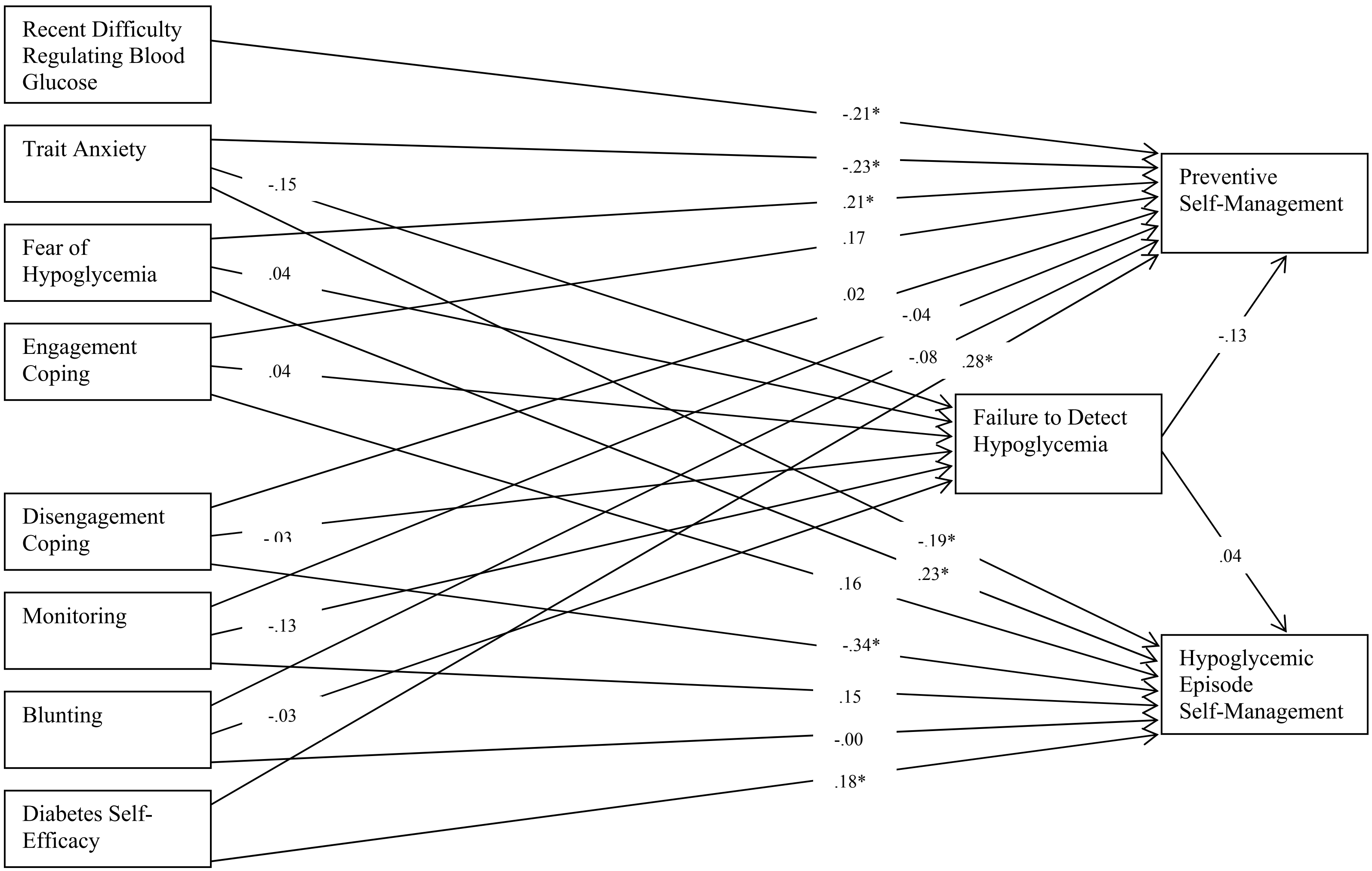

Figure 10. Standardized path coefficients for the model with the mediating error of failure to detect hypoglycemia.
*$p < .05$

Path analysis concerning failure to detect hyperglycemia. The χ^2 for this model was not statistically significant, χ^2 (5, N = 132) = 3.99, p = .55. Additional goodness-of-fit indices reflected good fit of the data with this model, except for the parsimony fit indices (see Table 10). No modification indices exceeded 3.84. Modification indices for γ supported that no direct paths were needed between diabetes self-efficacy, fear of hypoglycemia, or recent difficulty regulating blood glucose and failure to detect hyperglycemia, and no direct path was needed between difficulty regulating blood glucose and hyperglycemic episode self-management. However, the exogenous variables explained only 8% of the variance in failure to detect hyperglycemia. The variables affecting preventive self-management behavior accounted for 25% of the variance in combination, and 12% of the variance was accounted for in hyperglycemic episode self-management behavior. Figure 11 provides standardized path coefficients.

Comparison of values for total and indirect effects assessed mediational hypotheses. The model proposes that failure to detect hyperglycemia mediates the effects of the exogenous variables on both preventive and hyperglycemic episode self-management behavior. Contrary to the model, failure to detect hyperglycemia was not a mediator for any of these relationships, with none of the exogenous variables evidencing an indirect effect beyond its direct effect. Examination of specific paths indicated that although some exogenous variables had direct effects on management behavior, only blunting significantly affected failure to detect hyperglycemia, and failure to detect hyperglycemia did not significantly affect either preventive or hyperglycemic episode self-management, precluding any mediational effect.

Table 10

Goodness of Fit Indices for Failure to Detect Hyperglycemia Path Analysis (N = 132)

χ^2	*df*	*p*	RMSEA	NFI	NNFI	CFI	GFI	AGFI	PNFI	PGFI	Critical *N*
3.99	5	.55	<.01	.98	1.07	1.00	.99	.93	.09	.08	496.50

Note. RMSEA=Root Mean Square Error of Approximation; NFI=Normed Fit Index; NNFI=Non-Normed Fit Index; CFI=Comparative Fit Index; GFI=Goodness of Fit Index; AGFI=Adjusted Goodness of Fit Index; PNFI=Parsimony Normed Fit Index; PGFI=Parsimony Goodness of Fit Index.

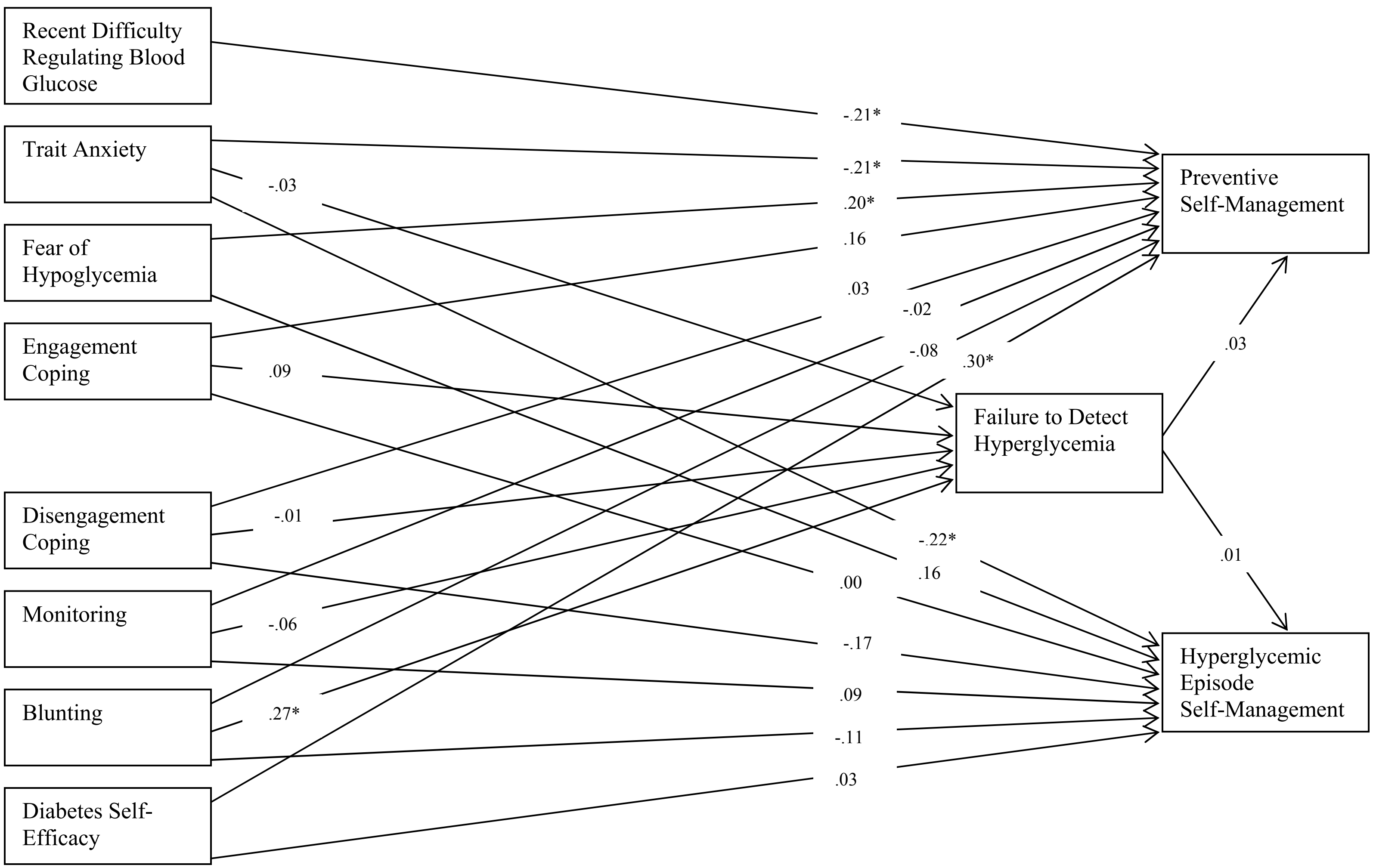

Figure 11. Standardized path coefficients for the model with the mediating error of failure to detect hyperglycemia.
**p* < .05

Path analysis concerning overestimation of normal blood glucose. The χ^2 approached statistical significance, χ^2 (5, N = 132) = 9.99, p = .08, and other goodness-of-fit indices suggested that the model might warrant modification (see Table 11). Modification indices reflected that freeing the path from difficulty regulating blood glucose to overestimation of normal blood glucose would reduce the chi square statistic. Modification indices for γ supported that no direct paths were needed between diabetes self-efficacy or fear of hypoglycemia and overestimation of blood glucose, or between difficulty regulating blood glucose and hyperglycemic episode self-management. However, the exogenous variables explained only 3% of the variance in failure to detect hyperglycemia. The variables affecting preventive self-management behavior accounted for 28% of the variance in combination, and 12% of the variance was accounted for in hyperglycemic episode self-management behavior. Figure 12 provides standardized path coefficients.

Comparison of values for total and indirect effects assessed mediational hypotheses. The model contends that overestimation of blood glucose should mediate the effects of the exogenous variables on both preventive and hyperglycemic episode self-management behavior. On the contrary, overestimation of blood glucose was not a mediator for any of these relationships, with none of the exogenous variables evidencing an indirect effect beyond its direct effect. Specific paths indicated that although some of the exogenous variables had direct effects on management behavior, and though overestimation of blood glucose significantly affected preventive self-management, none of the variables significantly affected overestimation of blood glucose.

Table 11

Goodness of Fit Indices for Overestimation of Normal Blood Glucose Path Analysis (N = 132)

χ^2	*df*	*p*	RMSEA	NFI	NNFI	CFI	GFI	AGFI	PNFI	PGFI	Critical *N*
9.99	5	.08	.09	.96	.68	.97	.99	.82	.09	.08	198.84

Note. RMSEA=Root Mean Square Error of Approximation; NFI=Normed Fit Index; NNFI=Non-Normed Fit Index; CFI=Comparative Fit Index; GFI=Goodness of Fit Index; AGFI=Adjusted Goodness of Fit Index; PNFI=Parsimony Normed Fit Index; PGFI=Parsimony Goodness of Fit Index.

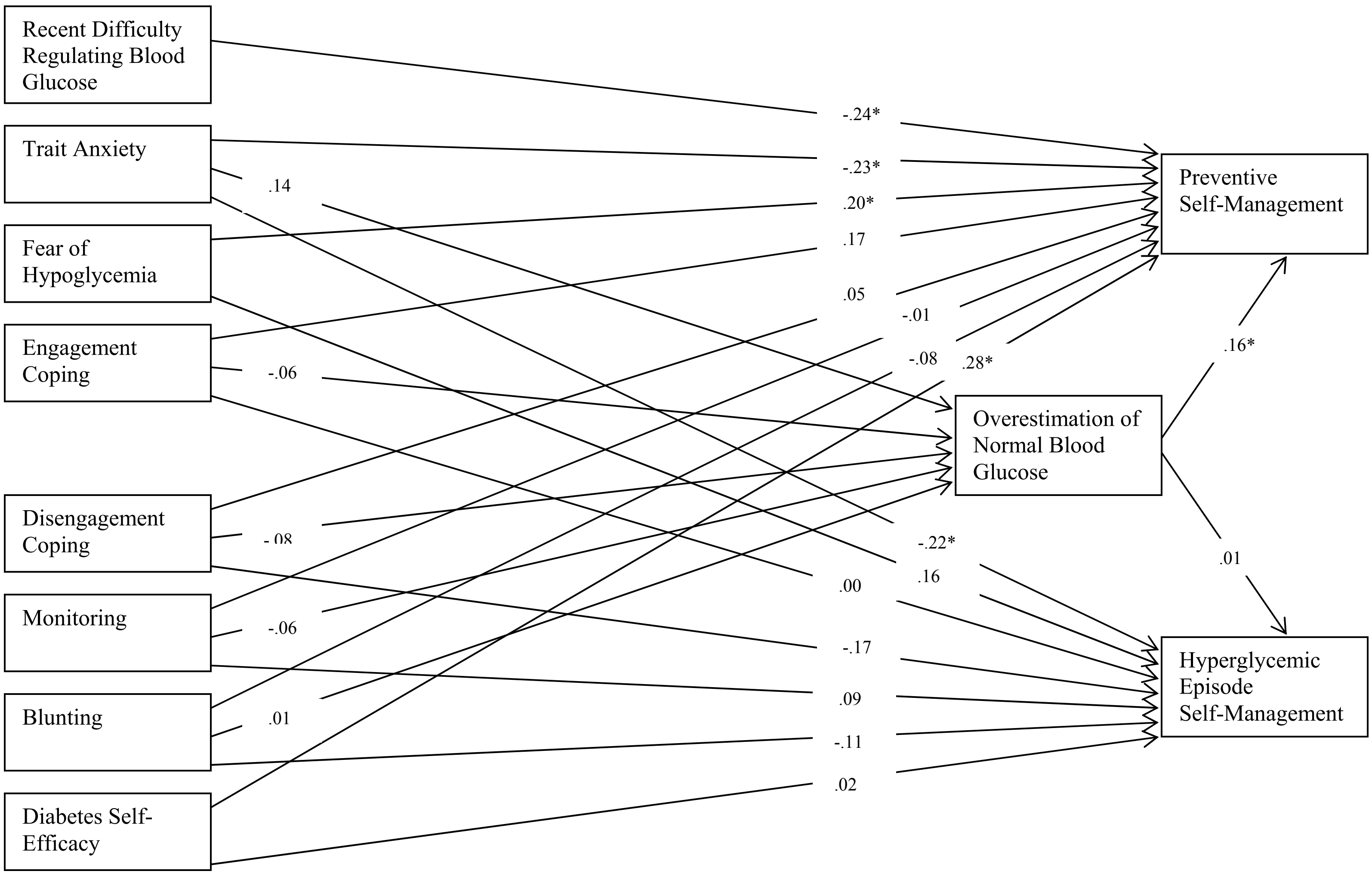

Figure 12. Standardized path coefficients for the model with the mediating error of overestimation of normal blood glucose.
**p* < .05

Supplementary Analyses

Child-report of self-management behavior was used in the path analysis of the proposed model to maintain consistency in reporting source, but parent-report of child self-management behaviors was also assessed in the study. To explore the agreement between child- and parent-report, a Pearson correlation coefficient compared scale scores. Parent and child-report of preventive management items were significantly correlated at $r = .47$, $p < .001$ (medium to large effect size). Parent and child-report of hypoglycemic episode management items were significantly correlated at $r = .19$, $p = .04$ (small to medium effect size), and hyperglycemic episode management items were significantly correlated at $r = .36$, $p < .001$ (medium effect size).

Because no significant relationships between the perceptual errors and preventive or acute episode self-management behaviors emerged, proposed analyses to assess for a moderating effect of child-reported blood glucose threshold for treatment or of regimen responsibility were not warranted.

SUMMARY AND CONCLUSIONS

Perceptual Accuracy in This Sample

Consistent with previous research concerning perceptual accuracy, considerable variability existed both within and across participants in this sample, with the individual mean perceptual accuracy indices ranging from -64.30% to 81.30% and a mean overall accuracy index of 14.73%. Also consistent with previous research, results indicated that children and adolescents tend to be less accurate in blood glucose estimation than are adult patients. Adults' clinically accurate estimates typically range from 42% to 90% (Cox et al., 1985), compared with the range from 0% to 81% and the mean of 35% in this sample. As is typical for both children and adults, failure to detect extreme levels of blood glucose was the most common clinically serious error in this sample.

When comparing these results with specific studies of adolescent perceptual accuracy, this sample evidenced a lower mean accuracy index (14.73%) than Freund and colleagues (1986; 25%), Metzler and colleagues (2003; 37%), Gonder-Frederick et al. (1991; 29%), and Wiebe et al. (1994; 38%) but higher than Ruggerio et al. (1991; 7%), and Nurick and Johnson (1991; 7%). When examining the correlation between estimated and observed blood glucose, the mean correlation of .30 in this sample was comparable to Ruggiero and colleagues (1991) findings (.29) but lower than Freund et al.'s (1986) findings (.51).

Overall, the results of this study support previous findings that adolescent patients with diabetes make potentially serious errors in estimation of blood glucose levels more so than adults and that the most common clinical relevant error is failure to detect hypo- or hyperglycemia, with the latter being most common in this sample. They also support the trend for females to be more accurate than males and for older participants to be more accurate than younger participants. It is interesting to note, however, the differential relationship between age and specific perceptual errors; older age was related to decreased failure to detect hyperglycemia and increased failure to detect hypoglycemia. The mechanisms for this discrepancy are unclear, but it highlights the importance of examining specific perceptual errors and not just global perceptual accuracy. Illness duration and method of insulin administration were unrelated to global perceptual accuracy in this sample. Results also converge with research documenting that practice with blood glucose estimation and measurement alone does not significantly improve accuracy.

Overall Evaluation of the Models

Fit indices for the models including failure to detect hypo- and hyperglycemia generally indicated a good fit of the data with the model. However, these findings may be attributable to the fact that the models are not highly restrictive, as is reflected by the dramatic reduction in the values of the parsimony goodness of fit indices. The model concerning overestimation of normal blood glucose did not fit as closely but still resulted in only one modification index exceeding the critical value. Examination of global goodness of fit indices would provide overall support for the models; however, a closer examination of specific hypotheses lends little support.

None of the more specific hypotheses concerning mediation were supported in any of the models, due to a general lack of relationships between the exogenous variables and perceptual errors as well as between any of the perceptual errors and either preventive or acute self-management behavior. No significant path coefficients existed between the exogenous variables and failure to detect hypoglycemia, and of the variables relating to failure to detect hyperglycemia, blunting was the only significant path coefficient. For variables relating to overestimation of normal blood glucose, no path coefficients were significant. This general lack of meaningful relationships with perceptual errors may reflect that anxiety, coping, and attentional style (or psychosocial variables in general) do not meaningfully impact perceptual accuracy in adolescents with diabetes. Other potential mechanisms of failure to detect hypoglycemia that have been suggested include cognitive factors such as attentional mechanisms, competing motivations, misattribution of symptom information, and inaccurate symptom beliefs and physiological factors such as decreased hormonal response, autonomic neuropathy, or cognitive impairment due to low blood glucose (Bradley et al., 1998; Gonder-Frederick, Cox, Kovatchev, Schlundt, & Clarke, 1997).

The percentages of variance explained by the exogenous variables on the endogenous variables were relatively small for each of the models. Only 5% of the variance was explained in failure to detect hypoglycemia, 8% in failure to detect hyperglycemia, and 3% in overestimation of normal blood glucose. The variables affecting preventive self-management behavior accounted for between 25% and 28% of the variance in combination, variables affecting hypoglycemic episode self-management accounted for 22%, and variables affecting hyperglycemic episode self-management behavior accounted for 12%.

The lack of relationships between self-management behavior and the perceptual errors in this study is surprising in theory but may be attributable to the method of measurement used. Specifically, retrospective self-report quantified both preventive and acute self-management behaviors, whereas perceptual accuracy was measured prospectively. Preventive self-management behavior was retrospective self-report of the past three days, whereas perceptual accuracy information was collected during the camp week. Further, concerning acute episode self-management, participants reported on their self-management behavior during their last hypo- and hyperglycemic episodes. The ability to report on this automatically requires the participant to have detected that episode. Thus, it is logical that management behavior in a detected episode (as was reported) is likely to be different from management behavior in an undetected episode, and behavior in the latter situation is likely to have a stronger relationship with perceptual errors of failure to detect hypo- and hyperglycemia. Future research could rectify these concerns methodologically using concurrent assessment of both perceptual accuracy and management behavior, an extremely difficult task perhaps be made more feasible through computer-assisted testing.

In sum, although goodness of fit and modification indices generally lent support to the model, this is likely to be partially attributable to the nonrestrictive nature of the model. Examining the path coefficients, the mediational hypotheses, and the amount of variance explained generally reflects a lack of support of model hypotheses. This lack of support may be due in part to methodological limitations.

Strengths and Limitations

The present study has several notable strengths. First, the models tested in the study, although largely not supported in this sample, were based on thorough review of research and theory. Second, the sample size is notably large for a chronic illness sample and is the largest sample examining perceptual accuracy in children and adolescents to date. In addition, most of the measures used in the study were diabetes-specific. Perhaps most notably, this study looked at specific perceptual errors and their relationships with other variables, whereas most prior research has primarily examined the global accuracy index. Specific perceptual errors are all included in the accuracy index and may relate differentially to constructs of interest. Examining the global accuracy index alone may mask these differential relationships, whereas separately examining perceptual errors allows for examination of this possibility, as evidenced by participant age in this study. Finally, differentiation of self-management behavior into preventive and acute management behavior allowed for a more fine-grained examination.

The study also has several methodological limitations. First, the majority of the data were child/adolescent self-report, and many of the constructs are subject to social desirability, particularly self-management behavior. Concerning the assessment of self-management behavior, this study would have been improved by the use of Johnson and colleagues 24-hour recall interview (Johnson et al., 1986), currently considered the gold standard for assessing diabetes self-management, but interview format was not possible for the group administration format of this study. Another limitation of the self-management measure was its failure to account for method of insulin administration. Finally, as mentioned previously, self-report of self-management behavior retrospectively concerned the three days prior to camp, whereas the assessment of perceptual accuracy occurred during the camp week. Further, the assessment of acute episode self-management concerned detected episodes of hypo- and hyperglycemia, and assessment of management behavior in undetected episodes was not possible.

Also concerning the perceptual accuracy assessment, this study would have benefited from more estimated-observed blood glucose data points per participant. Participants were excluded if they did not have at least 10 pairs, and the sample mean was 13.78 pairs. Signal detection theory suggests that 100 or more stimulus-response pairs may be needed to properly assess perceptual capacity, and most perceptual accuracy studies include at least 30 pairs (Green & Swets, 1966; Rietveld, 1998). Having fewer pairs may have affected the stability of the perceptual accuracy data.

Implications for Future Research

Because support for the model in this sample was limited, future research on the model may not be very fruitful unless it includes improved and concurrent measurement of perceptual accuracy and self-management behavior. It is also notable that less than 10% of the variance was accounted for in each of the perceptual errors; it may be useful to identify other predictors of perceptual accuracy and error.

Research concurrently assessing perceptual accuracy and self-management decisions would be more helpful in examining a potential link between these two constructs. This may be made feasible through the use of hand-held computerized assessment in which a participant rates current symptoms, predicts current blood glucose, and indicates self-management behaviors in which he or she plans to engage given that predicted blood glucose prior to actually testing blood glucose level.

Given the propensity for children and adolescents to make blood glucose estimation errors, research should evaluate possible interventions to improve accuracy. Blood glucose awareness training has demonstrated efficacy with adult patients and has shown promise with adolescent patients as well (Cox et al., 1989; Cox et al., 1991; Cox et al., 1994; Cox et al., 1995). This method should be further investigated in adolescent samples and should be tailored to be developmentally appropriate for use with younger children and/or parents.

Conclusions

The theoretical models of perceptual accuracy and self-management behavior evaluated in this study evidenced a good global fit with the data, but results did not support specific hypotheses, and a relatively small amount of variance was explained. Contrary to expectations, the perceptual errors of failure to detect hypoglycemia and failure to detect hyperglycemia were not related to either preventive or acute episode self-management behavior, and overestimation of normal blood glucose was only related to preventive self-management behavior. Further, anxiety, coping and attentional style explained minimal variance in the perceptual errors. Results of the error grid analysis reflected considerable variability in perceptual accuracy within and across participants and indicated that adolescents are susceptible to frequently making clinically relevant blood glucose estimation errors, the most frequent in this sample being failure to detect hyperglycemia. In sum, these results support that adolescents with diabetes make a considerable number of estimation errors that have the potential to affect their self-management behavior; however, results in this sample generally did not support the proposed theoretical models.

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