Advancing the Science of Perceptual Accuracy in Pediatric Asthma and Diabetes

Mariella M. Lane, PhD
Department of Psychology, Texas A&M University

Objectives  To review research on perceptual accuracy in pediatric asthma and diabetes and to provide recommendations for future research efforts and clinical applications of the construct in these populations. Methods  A literature search was conducted using Medline and PsychInfo databases as well as the bibliographies of relevant articles. Results  Children and adolescents with asthma or diabetes evidence considerable variability in perceptual accuracy and frequently make clinically relevant errors that have the potential to affect self-management behavior. Conclusions  Recommendations for future research include studying distinct types of perceptual errors, empirically supporting the relationship between perceptual accuracy and relevant outcomes, identifying factors related to perceptual inaccuracy, and conducting longitudinal research and intervention studies. Recommendations for applying the construct in clinical practice include adopting an individualized approach to symptoms to guide patient education and management, identifying patients prone to making clinically relevant errors, and developing and implementing interventions to improve accuracy.

Key words  adolescents; asthma; children; diabetes; estimation accuracy; perceptual accuracy; symptom perception.

The primary purpose of this article is to provide recommendations to advance the field of perceptual accuracy research and to apply the construct meaningfully in clinical practice with children and adolescents with asthma or diabetes. To provide the reader with the essential context for these recommendations, this article offers a review of the concept of perceptual accuracy, why it is an important construct to measure, how it is measured, results of literature evaluating accuracy in asthma and diabetes, variables associated with accuracy and error, and existing interventions designed to improve accuracy in these populations. Following this review, recommendations to further the methodological rigor of perceptual accuracy research and for applying the construct in pediatric clinical practice are offered.

The Concept 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). It has also been defined as “the patient’s consciously appreciated sensation of a physiologic problem” (Banzett, Dempsey, O’Donnell, & Wamboldt, 2000; p. 1178). Simply put, symptom perception refers to detection of symptoms of a physical problem, perceptual accuracy (i.e., congruence between subjective assessment and objective state; Fritz, Yeung, et al., 1996) being the characteristic of interest. Both under-perception (i.e., failure to detect symptoms of a physical problem) and over-perception (i.e., detection of symptoms in the absence of a physical problem) can occur.

Symptom Perception Defined in Diabetes
In line with the conceptual definition above, 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, shakiness) that result from blood glucose fluctuations.
Literature on perceptual inaccuracy in diabetes typically focuses on under-perception of symptoms of low blood glucose and associated failure to detect hypoglycemia, often termed hypoglycemia unawareness (Clarke et al., 1995). However, Kovatchev, Cox, Gonder-Frederick, Schlundt, and Clarke (1998) indicated that although some patients detect no symptoms of hypoglycemia (i.e., under-perception), others experience symptoms at normal blood glucose levels (i.e., over-perception). Although less often discussed, similar perceptual errors can occur with respect to hyperglycemia. It is important to note that symptoms in diabetes are idiosyncratic, the methodological implications of which will be discussed later.

Symptom Perception Defined in Asthma
Symptom perception in asthma is the conscious awareness of or ability to detect physical symptoms of asthma (e.g., wheezing, chest tightness) and associated sensations such as breathlessness that result from airway obstruction (Rietveld, 1998; Rietveld & Brosschot, 1999; Rietveld et al., 1997). Inaccurate symptom perception can be described as discordance between actual airway obstruction and patient awareness of this obstruction. It can manifest as airway obstruction without symptoms (under-perception) or symptoms without airway obstruction (over-perception; Rietveld, 1998). Symptom perception is relevant to both detection of prodromal symptoms and recognition of an acute asthma exacerbation.

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. For both asthma and diabetes, health care providers frequently instruct patients to monitor symptoms to gauge current functioning and guide management decisions. Both over- and under-perception of symptoms could result in serious medical consequences and self-management errors. Pediatric and adult asthma research has supported the role of perceptual inaccuracy in asthma management, overutilization of medical resources, morbidity, and mortality (Davenport, Cruz, Stecenko, & Kifle, 2000; Fritz, McQuaid, Spirito, & Klein, 1996; Kifle, Seng, & Davenport, 1997; Kikuchi, Okabe, & Tamura, 1994; Magdele, Berar-Yanay, & Weiner 2002; Rubenfeld & Pain, 1976; Strunk, 1987; Yoos & McMullen, 1999; Zach & Karner, 1989).

Some intervention studies in diabetes have supported a link between improving accuracy and relevant outcomes. Driving performance can be significantly impaired by relatively mild hypoglycemia (Cox, Gonder-Frederick, Kovatchev, Julian, & Clarke, 2000), and long-term follow up of adults who underwent an intervention to improve accuracy reflected fewer automobile crashes than the control group (Cox, Gonder-Frederick, Julian, & Clarke, 1994). Some studies have suggested that perceptual accuracy positively correlates with glycosylated hemoglobin, and intensive intervention may improve both (Cox et al., 1991, 1994). Intervention can also improve detection of hypoglycemic episodes, and may preserve the counterregulatory responses associated with improved glycemic control (Kinsley et al., 1999).

Methods for Quantifying Perceptual Accuracy
Measuring Perceptual Accuracy in Diabetes
Symptom perception research often compares the subjective self-report of a patient’s perceived symptoms (e.g., shakiness) to an objective measure of functioning (e.g., observed blood glucose; Cox, Gonder-Frederick, Antoun, Cryer, & Clarke, 1993). However, use of the symptom intensity method in diabetes 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 (Freund, Bennett-Johnson, Rosenbloom, Alexander, & Hansen, 1986; Gonder-Frederick & Cox, 1991). However, individual symptom-blood glucose relationships can be identified and may be reliable over time (Cox, Gonder-Frederick, Pohl, & Pennebaker, 1983; Pennebaker et al., 1981; Pennebaker, Gonder-Frederick, Cox, & Hoover, 1985).

Assessment of perceptual accuracy in diabetes 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), termed blood glucose estimation accuracy instead of symptom perception. Initially, data analysis consisted of examining the mean correlation between a patient’s estimated and observed functioning over successive trials. Then Cox and colleagues introduced error grid analysis as an approach to quantifying perceptual accuracy that accounts for the relative clinical importance of perceptual errors (Cox et al., 1989).

Error grid analysis, which involves plotting an individual’s estimated and observed blood glucose over successive trials and observing the clinically meaningful
zone into which plots fall, provides the frequency of clinically accurate estimates as well as benign errors and clinically important errors (i.e., failure to detect hypo- and hyperglycemia, estimation of these states when one is euglycemic, and mistaking hypo- for hyperglycemia and vice versa; Figure 1). A zones include clinically accurate estimates of blood glucose, and B zones reflect clinically benign estimation errors. C zones include clinically significant errors likely to lead to overcorrective treatment whereas D zones include failures to detect extreme levels of blood glucose. E zones reflect mistaking hypo- 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 of such errors than accurate estimates (Cox et al., 1989). An AI of zero reflects equal numbers of accurate and clinically relevant, inaccurate estimates.

**Measuring Perceptual Accuracy in Asthma**

In asthma, symptom perception has typically been assessed in one of three ways: (a) comparing the subjective self-report of a patient's perceived symptoms (e.g., reported breathlessness) to an objective measure of pulmonary functioning (e.g., Peak Expiratory Flow Rate or PEFR), (b) comparing an observed measure of functioning (e.g., PEFR) to estimated lung functioning predicted by the patient (e.g., patient prediction of PEFR), or (c) assessing the perception of externally applied resistive loads by experimentally manipulating airflow and asking patients to rate symptoms or report noticed changes (Fritz, McQuaid, Nassau, Klein, & Mansell, 1999; Fritz, Yeung, et al., 1996; Rietveld, 1998; Rietveld & Brosschot, 1999; Rietveld, Prins, & Kolk, 1996). A correlational approach is a common data analytic strategy, but researchers are beginning to abandon it because of a variety of limitations, including inability to capture information regarding type of perceptual error (Fritz, Yeung, et al., 1996).

Fritz and Wamboldt (1998) adapted Cox and colleagues’ error grid analysis for application to asthma. Klein et al. (2004) recently modified this grid to promote clinical utility. Similar to the diabetes error grid, Klein and colleagues’ asthma risk grid consists of plotting estimated PEFR against observed PEFR (both converted into percent of personal best units for interindividual comparison) over successive trials and observing the clinically meaningful zone into which plots fall (Figure 2). Vertical lines mark 50%, 80%, and 100% of the child’s best value (corresponding to the National Heart, Lung, and Blood Institute “Green,” “Yellow,” and “Red” zone guidelines; National Institutes of Health, 1997). Plots fall into one of three clinically meaningful zones and percentage of plots in each zone is calculated, summing to 100%. The Accurate zone includes estimates within ±10% of the actual value, detection of compromised functioning, and correct recognition of adequate functioning. The Danger zone includes failure to recognize clinically significant compromised functioning, and the Symptom Magnification zone reflects underestimation of PEFR that may lead to over-utilization of medical resources.

**Research Assessing Perceptual Accuracy in Healthy Individuals**

Considerable research has investigated healthy individual’s ability to perceive a variety of autonomic symptoms (e.g., blood pressure, heart rate, skin temperature; Fritz, Yeung, & Taitel, 1994; Pennebaker et al., 1985). A review of these data is beyond the scope of this article, but in
general, healthy participants’ evaluation of autonomic symptoms are often inaccurate, with correlation coefficients between subjective and objective measures typically ranging from .15 to .25 (Pennebaker, 1987). However, the ecological validity of these paradigms is questionable, and one might speculate that patients whose symptoms are relevant indicators of physical functioning and have adaptive utility may be more accurate (Pennebaker et al., 1985). Some research has compared the ability of healthy children and those with asthma to detect resistive loads on breathing, with some results suggesting that asthmatic children are more sensitive to/accurate at detecting loads (Fritz et al., 1999; McQuaid, Fritz, Yeung, Biros, & Mansell, 1996), while other results suggest they are less so (Dahme, Richter, & Mass, 1996; Rietveld, Prins, et al., 1996). No research was found investigating the ability of healthy individuals to estimate blood glucose.

**Perceptual Accuracy in Pediatric Diabetes**

Ability to accurately estimate blood glucose varies greatly across adult diabetes patients, with clinically accurate estimates from error grid analysis typically ranging from 40 to 90% (Cox et al., 1985, 1989; Fritsche, Stumvoll, Renn, & Schmulling, 1998). Error grid analyses indicate that adults make clinically serious errors up to 20% of the time (Cox et al., 1985).

Adolescent patients also vary considerably in their ability to estimate blood glucose level, but they are significantly less accurate in blood glucose estimation than are adults. Mean accuracy indices for adolescents have ranged from 7 to 38 (Freund et al., 1986; Lane & Heffer, 2005; Meltzer, Bennett-Johnson, Pappachan, & Silverstein 2003; Nurick & Johnson, 1991; Ruggiero, Kairys, Fritz, & Wood, 1991; Wiebe, Alderfer, Palmer, Lindsay, & Jarrett, 1994). Some adolescents have negative AI, indicating they make more clinically relevant estimation errors than accurate estimates (Wiebe et al., 1994). Overall, children and adolescents tend to make accurate estimates, clinically benign errors, and clinically relevant errors each approximately 1/3 of the time (Gonder-Frederick, Snyder, & Clarke, 1991; Meltzer et al., 2003; Ruggiero et al., 1991). Mean correlations between estimated and observed blood glucose have ranged from .29 to .51 with a wide range in individual correlations (Freund et al., 1986; Ruggiero et al., 1991).

Accuracy indices generally are higher in older adolescents than in younger ones (Freund et al., 1986; Lane & Heffer, 2005; Meltzer et al., 2003; Nurick & Johnson, 1991; Ruggiero et al., 1991), and younger children are even poorer at estimating blood glucose than adolescents. Gonder-Frederick et al. (1991) reported a mean AI of -0.68 in their small sample of children 6–12 years of age. As a group the children made clinically significant errors at a similar frequency to accurate estimates, and over half of the individual AIs were negative (Gonder-Frederick et al., 1991). Gonder-Frederick et al. (2004) reported a mean AI of 4 in another sample of children 6–11 years, with a mean of 23% for accurate estimates and 19% for clinically significant errors.

Across child and adolescent studies, failure to detect extreme levels of blood glucose tends to be the most common clinically serious error (Gonder-Frederick et al., 2004; Kovatchev et al., 1998; Lane & Heffer, 2005; Ruggiero et al., 1991; Ryan, Suprasongsin, Dulay, & Becker, 2002), with the exception of Meltzer et al.’s (2003) study in which the most common error was misestimation of normal blood glucose likely to lead to overcorrective treatment. 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). Overall, research reflects 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).
Perceptual Accuracy in Pediatric Asthma

Studies investigating the perceptual accuracy of pediatric asthma patients have cited a wide range of perceptual accuracy with at least a significant minority of children classified as inaccurate perceivers (Cabral, Conceicao, Saldiva, & Martins, 2002; Creer, Harm, & Marion, 1988; Fritz, Klein, & Overholser, 1990; Fritz, McQuaid, et al., 1996; Rietveld et al., 1997; Sly, Landeau, & Weymouth, 1985; Yoos & McMullen, 1999). Perceptual inaccuracy in children with asthma includes both under- and over-perception of symptoms.

A factor complicating summarization of research using the symptom intensity method is the fact that the meaning of a strong negative or strong positive correlation varies across studies based on methodology. Among pediatric studies in which a strong negative correlation reflects accuracy, Chai Purcell, Brady, & Falliers (1968, as cited in Taplin & Creer, 1978) reported individual mean correlations ranging from –.25 to –.70, and Yoos and McMullen (1999) reported a sample mean correlation of –.55. In Fritz et al.’s (1990) study a strong positive correlation reflected accuracy; individual mean correlations between children’s subjective report of symptoms and observed PEFR ranged from –.16 to .86, with a sample mean correlation of .38. Further, research has indicated that many children have no significant correlation between symptom scores and lung functioning (Cabral et al., 2002; Rietveld et al., 1997; Sly et al., 1985; Tsanakas, 1986).

Using the patient prediction method, Fritz, McQuaid, et al. (1996) examined patient estimated and observed pulmonary functioning in children with asthma. The FEF_{25-75} (forced expiratory flow in the midportion of a breath) accuracy correlations ranged from –.54 to .82 with a mean of .17, and the PEFR accuracy correlations ranged from –.39 to .88 with a mean of .29. Overall, wide variation exists in the perceptual accuracy of pediatric asthma patients, a sizeable minority exhibiting significant inaccuracy. No published research has applied the asthma risk grid to the measurement of PEFR estimation accuracy in children, and a correlational approach to data analysis has notable limitations (Fritz, Yeung, et al., 1996).

Accuracy of Parents and Parent-Child Concordance

Diabetes

Using error grid analysis, Gonder-Frederick et al., (1991) reported that both parents and children demonstrated poor blood glucose estimation accuracy, making clinically relevant errors as frequently as accurate estimates, with no significant difference between parents and children for mean accuracy or error scores. Accuracy scores of parents and children were correlated at \( r = 0.30 \), and parents were more accurate for younger children. Both parents and children tended to underestimate blood glucose overall, but some differences in error type emerged between parents and children. Children made C, D, and E zone errors about equally, whereas parents made D zone errors most often. Children were more likely than parents estimate their blood glucose as hypoglycemic when it was in the hyperglycemic range (i.e., Lower E zone).

Asthma

Because management of asthma is a joint undertaking between parent and child, evaluating the accuracy of parent’s assessments of their children’s functioning, as well as concordance between parent and child assessments is important. Some researchers have found parents’ perceptions of children’s airway obstruction to be quite inaccurate and unrelated to physical functioning (Horak, Grassi, Skladal, & Ulmer, 2003; Panditi & Silverman, 2003; Sly et al., 1985; Yoos & McMullen 1999). Yoos, Kitzman, McMilen, and Sidora (2003) reported similar accuracy between parents and children and consistency in the direction of errors, whereas Panditi and Silverman (2003) reported poor agreement between parent and child report of symptoms.

One could hypothesize that parental symptom reporting patterns may relate to accuracy in evaluating a child’s physiological functioning. Fritz, McQuaid, et al. (1996) found that children of parents with more extreme tendencies to report their own physical symptoms may be more accurate than children of parents with moderate symptom reporting patterns. Unfortunately, these data are extremely difficult to interpret because the group of parents with extreme symptom reporting includes both those who over- and under-report.

Variables Related to Perceptual Accuracy and Error

Diabetes

A small body of research has investigated the relationship of demographic, illness-related, and psychological variables to accuracy and/or error in children and adolescents with diabetes. Results frequently but not exclusively suggest that older children are more accurate estimators (Gonder-Frederick et al., 1991; Meltzer et al., 2003; Lane & Heffer, 2005; Ruggiero et al., 1991; Ryan
et al., 2002). Results on gender differences are equivocal (Lane & Heffer, 2005; Meltzer et al., 2003; Ruggiero et al., 1991). Regarding illness-related variables, duration of diabetes and experience with self-monitoring of blood glucose have not been related to AI in children and adolescents (Gonder-Frederick et al., 1991; Lane & Heffer, 2005; Ruggiero et al., 1991). Mean blood glucose level, blood glucose variability, and experience of extreme blood glucose episodes have been negatively related to AI and may predict estimation errors (Gonder-Frederick et al., 1991; Lane & Heffer, 2005; Meltzer et al., 2003; Wiebe et al., 1994). Even fewer studies have investigated the relationship between psychological variables and accuracy; those that exist focus on anxiety and yield equivocal results (Ryan et al., 2002; Wiebe et al., 1994).

**Asthma**

Regarding demographic variables, results are equivocal concerning the relationship between age and perceptual accuracy (Cabral et al., 2002; Fritz et al., 1990; Fritz, McQuaid, et al., 1996; Yoos & McMullen, 1999; Yoos et al., 2003). Gender has not been related to accuracy (Cabral et al. 2002; Fritz et al., 1990; Yoos et al., 2003). Yoos et al. (2003) reported that White children and those of upper socioeconomic status (SES) families were most accurate, but not significantly so after accounting for illness severity.

Illness-related variables that do not appear relevant to accuracy include age at diagnosis, duration of illness, and use of preventive medication (Cabral et al., 2002; Fritz et al., 1990; Fritz, McQuaid, et al., 1996; Rietveld, Prins, & Colland, 2001). Some studies suggest that asthma severity is negatively related to accuracy (Julius, Davenport, & Davenport, 2002; Yoos et al., 2003), whereas others have cited no relationship between the two (Cabral et al., 2002; Fritz et al., 1990). Slow decline in pulmonary functioning and habituation to prolonged symptoms may be related to decreased accuracy; patients with prolonged airway obstruction perceive symptoms less well than patients with acute onset airway obstruction (Rietveld & Everaerd, 2000). Although Fritz et al. (1990) reported that accuracy was unrelated to both PEFR variability and current PEFR, some research suggests that patients with lower lung functioning at the point of accuracy assessment tend to be less accurate (Apter et al., 1997; Yoos et al., 2003), perhaps because of hypoxia or hypercapnia and associated cognitive impairment (Eckert, Catcheside, Smith, Frith, & McEvoy, 2004).

Several studies have indicated that patient-reported symptoms such as dyspnea are independent of lung functioning, suggesting that symptoms are a subjective experience more related to psychological factors than to airway pathophysiology (Rietveld, Everaerd, & van Beest, 2000; Rietveld et al., 2001). Some psychological variables proposed to impact accuracy include anxiety/negative mood, defensive or repressive style, cognitive abilities, and familial teaching/modeling (Fritz et al., 1994; Fritz, Yeung, et al., 1996). Some research has demonstrated that negative mood influences the subjective experience of breathlessness (not objective lung functioning) and is associated with increased symptom reporting and diminished perceptual accuracy (Lehrer, Feldman, Giardino, Song, & Schmaling, 2002; Main, Moss-Morris, Booth, Kaptein, & Kolbe, 2003; Rietveld, Everaerd, & van Beest, 1999: Rietveld & Prins, 1998). However, Fritz, McQuaid, et al. (1996) reported that trait anxiety was not related to perceptual accuracy in children. Research is equivocal about the impact of a defensive or repressive style on accuracy (Fritz, McQuaid, et al., 1996; Isenber, Lehrer, & Hochron, 1997; Lehrer et al., 2002; Steiner, Higgs, Fritz, Laszlo, & Harvey 1987). Cognitive developmental level may also be related to perceptual accuracy (Fritz, Yeung, et al., 1996; Yoos & McMullen, 1999), and Fritz, McQuaid, et al. (1996) reported that an intelligence estimate was related to increased perceptual accuracy in children.

**Interventions for Improving Accuracy**

**Interventions in Diabetes**

Though some adults demonstrate improved estimation accuracy following blood glucose feedback interventions, larger studies have suggested that practice with blood glucose self-monitoring and provision of feedback does not yield substantial improvement in accuracy (Gross, Levin, Mulvill, Richardson, & Davidson, 1984; Gross et al., 1983; Malerbi & Matos, 2001; Meltzer et al., 2003; Schandry & Leopold, 1996; Schandry, Leopold, & Vogt, 1996). A structured inpatient program that did not target improvement in estimation accuracy also was not sufficient to exert an effect (Fritsche et al., 1998).

Cox and colleagues have developed and modified Blood Glucose Awareness Training (BGAT), a weekly group training program designed to improve blood glucose estimation accuracy (Cox, Carter, Gonder-Frederick, Clarke, & Pohl, 1988; Cox et al., 1989, 1995). The intervention
is designed to increase: (a) awareness of one’s idiosyncratic symptoms that reliably co-vary with blood glucose, (b) awareness of inaccurate symptom beliefs and other factors causing errors, and (c) knowledge of effects of external factors on blood glucose. Patients are provided with psychoeducational material and learn to plot and interpret their own error grid. Cox et al. (1991) have also developed an intensive version of BGAT. Multiple studies have supported the efficacy of BGAT in improving blood glucose estimation accuracy and the detection of low blood glucose levels (Cox et al., 1989, 1991, 1994, 1995).

**Interventions in Asthma**

Interventions seeking to improve perceptual accuracy typically employ patient practice of PEFR self-monitoring and either symptom intensity rating or PEFR prediction. Results have been mixed but yield predominantly no effect on accuracy (Fritz, McQuaid, et al., 1996; Reeder, Dolce, Duke, Racznyski, & Bailey, 1990; Rietveld, Kolk, & Prins, 1996; Schandry et al., 1996; Silverman et al., 1987; Sly et al., 1985; Wagner & Ruggiero, 2004). No comprehensive psychoeducational intervention has been developed to improve perceptual accuracy in asthma.

**Recommendations for Advancing Perceptual Accuracy Research**

**Recommendations for Both Pediatric Asthma and Diabetes Research**

Examine Distinct Types of Perceptual Errors

Most research using error grid analysis has focused on the AI and variables related to global perceptual accuracy. Future research should examine each type of specific perceptual error instead of or in addition to a global AI. Because calculation of the AI (i.e., subtracting summed percentages of different types of errors from the percentage of clinically accurate estimates) includes multiple perceptual errors in the formula, two individuals with the same AI may have arrived at their respective values due to very different errors (e.g., failure to detect hypoglycemia versus failure to detect hyperglycemia versus underestimating or overestimating normal blood glucose). Further, differential relationships may exist between specific errors and relevant constructs (e.g., anxiety), and use of the global AI may mask these relationships. For example, a recent study in a sample of children and adolescents with diabetes found differential relationships between age and specific type of perceptual error; failure to detect hypoglycemia was positively related to age, whereas failure to detect hyperglycemia was negatively related to age (Lane & Heffer, 2005).

Support the Relationship Between Perceptual Accuracy and Self-management

Although the relationship between perceptual accuracy and self-management behavior seems intuitive, it needs to be empirically demonstrated. Examination of specific perceptual errors and specific self-management behaviors is needed. Concurrent assessment of both perceptual accuracy and self-management behaviors would be ideal. This may be 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 before actually testing blood glucose level.

Admittedly, research on the relationship between perceptual accuracy and self-management behavior is complicated by the typical reliance of a child or adolescent on a parent or other adult to monitor self-management (Banzett et al., 2000), and this should be taken into account. One could hypothesize that parental modeling may be related to child report of symptoms or child accuracy in evaluating physiological functioning. Parents potentially play a key role in modeling or teaching children about how to attend to, ignore, interpret, and respond to symptoms—a fruitful area of research.

Nonadherence may be inadvertent or purposeful and links to perceptual inaccuracy should be studied. Wamboldt (1998) suggests that failure to perceive aversive symptoms may inhibit self-management because of the absence of distress that often initiates behavior and the absence of negative reinforcement that occurs when medication use reduces symptom distress. Alternatively, patients who believe they are accurate may not take medications when asymptomatic. Wamboldt (1998) describes a pilot study in which adolescents with asthma who were more accurate were less likely to comply with oral steroids and more likely to comply with theophylline, suggesting that accuracy may be differentially predictive of medication adherence.

Conduct Longitudinal Studies of Perceptual Accuracy

Longitudinal research is needed to further assess reliability of relationships between symptoms and physical functioning, as well as to evaluate developmental changes in accuracy. Such research is also integral to determining whether accuracy is more of a trait-like or state-like phenomenon, an important question impacting the interpretation of perceptual accuracy research. Longitudinal research is also important to determine whether subgroups of consistently accurate/inaccurate children can be identified.
Identify Predictors of Inaccuracy and Develop Models of Accuracy and Error

Although research examining a variety of potential predictors of accuracy has begun, its development is insufficient to reliably predict which individuals are most at risk for clinically serious errors. Learning how to identify such children is an important research effort with clear clinical implications. Evaluating mechanisms by which accuracy may improve with increasing age (e.g., cognitive development, illness knowledge, social learning) would also be of interest.

Few studies evaluate potential predictors of perceptual accuracy in diabetes, and those that do have primarily focused on demographic and illness-related variables. Examining other constructs, such as inaccurate symptom beliefs, attentional style, or anxiety, may prove fruitful and inform intervention efforts (Wiebe et al., 1994). Kovatchev et al.’s (1998) stochastic model of self-regulation (internal condition → symptom perception → appraisal → self-regulation decision) or Cox et al.’s (1993) biopsychosocial model for detection of hypoglycemic symptoms (physical reaction → physical consequences → symptom detection → symptom interpretation) may be applied to conceptualize and study "breakdowns" in the path from impaired functioning to detection of the problem to intervention.

A variety of mechanisms for perceptual inaccuracy in asthma have been proposed and may guide research (Creer, 1983; Rietveld, 1998; Rietveld & Brosschot, 1999; Rietveld & Prins, 1998). Research examining proposed mechanisms should incorporate PEFR estimation and asthma risk grid analysis. Some research confuses constructs of perceptual accuracy with symptom appraisal and decision to initiate treatment (Hardie, Gold, Janson, Carriero-Kohlman, & Boushey, 2002), and applying a more standard methodology for assessing accuracy using the asthma risk grid will facilitate interpretation and comparison of results.

Conduct Intervention Studies for Children and Adolescents

Self-monitoring or practice with estimation generally does not yield improvements in perceptual accuracy in either asthma or diabetes; more complex interventions are required. For both pediatric asthma and diabetes, research needs to develop or amend current interventions to be developmentally appropriate and evaluate their efficacy. Research efforts may aim to identify necessary components for improvement to make interventions more parsimonious, and interventions may benefit from individual tailoring to predominant type(s) of error. Because linking interventions to outcomes is key, intervention studies should seek to demonstrate the effect of improved accuracy on clinical outcomes such as morbidity, healthcare utilization, and health-related quality of life.

Cox and colleague’s BGAT intervention has demonstrated efficacy in improving blood glucose estimation accuracy in both adults and in adolescents, primarily reducing failure to detect hypoglycemia. Identifying key components of this intervention and examining mechanisms of efficacy for BGAT, particularly internal versus external cue training, may be of use, as well as identifying factors predicting treatment success and maintenance of gains. Most Cox and colleague’s samples have mean ages in the 30s or 40s (Cox et al., 1991, 1993, 1994, 1995); the program should be further evaluated in adolescent samples and modified for developmentally appropriate use with younger children and their parents. Further investigation of intensive BGAT versus the standard program and independent evaluations of BGAT efficacy are also needed.

An intervention for improving PEFR estimation accuracy in asthma is currently underway and can be modeled after key concepts of the BGAT program by targeting: (a) awareness of idiosyncratic symptoms that reliably covary with peak flow, (b) awareness of inaccurate symptom beliefs and other factors causing errors, and (c) knowledge of effects of external factors on pulmonary functioning. Children and adolescents can be trained in use and interpretation of both the peak flow meter and the asthma risk grid. Examining the relationships between individual symptom ratings from a symptom checklist and PEFR can identify idiosyncratic symptoms that predict compromised pulmonary functioning for a given patient. Interventions could also perhaps be individually tailored in accordance with predominant type of error (i.e., Danger zone vs. Symptom Magnification zone).

Recommendations Specific to Diabetes Research

Consider the Ramifications of Incorporating B Zones with A Zones

One of Klein et al.’s (2004) modifications to the asthma risk grid from the grid originally modified for asthma by Fritzand Wamboldt (1998) is that the “Benign Overestimation” and “Benign Underestimation” zones were incorporated with the accurate zone. Similarly in the diabetes error grid, because B zone estimates do not have clinically relevant implications for self-management behavior, perhaps clinically irrelevant B zone estimates that are not within 20% of observed blood glucose should be considered essentially the same as A zone estimates. A
zone and B zone estimates have the same implications for self-management (i.e., do nothing), making the requirement that an estimate be within 20% of the observed value arbitrary and clinically irrelevant.

**Recommendations Specific to Asthma Research**

**Employ an Individualized Approach to Symptoms**

For symptom perception in asthma, an implicit assumption has been that symptoms have the same meaning about pulmonary functioning for different people, or that they reliably covary with pulmonary functioning across patients. This is an empirical question, and one not supported in diabetes research. Yoos and McMullen (1999) reported that when children were asked to describe a bad breathing day, cough was the most common symptom reported (53%), followed by wheeze (46%), and 19% of children did not mention cough, wheeze, or shortness of breath. Asthma research employing the symptom intensity method should assess numerous symptoms, not just breathlessness, and should compare their relative importance as each may not be equally valuable in predicting lung functioning, especially across patients. The finding that symptom descriptors may vary according to ethnicity (Hardie et al., 2000) further supports the use of the PEFR prediction method to evaluate accuracy instead of the symptom intensity method. But, both research and clinical interventions should employ an individualized approach to determine which specific symptoms are related to impaired pulmonary functioning for a specific person.

**Examine Perceptual Accuracy for Slow Decline in Pulmonary Functioning Versus Acute Onset**

Individuals with slow decline in pulmonary functioning may be less likely to perceive symptoms or changes in functioning than those with acute onset airway obstruction and may therefore experience increased risk for morbidity and mortality (Rietveld & Everaerd, 2000). Should perceptual accuracy be poorer for those who experience slow declines in functioning and are likely to habituate to this level of functioning, this may be a target for intervention. In fact, the most effective intervention for those with incremental decline in pulmonary functioning may be different than for those who experience more acute declines. The relative importance of symptoms to which one attends may differ for incremental versus acute decline (e.g., fatigue versus breathlessness). Training individuals to detect slow decline in functioning may prove more difficult, and increased reliance on PEFR monitoring may be indicated for such patients.

**Evaluate the Asthma Risk Grid**

Research should seek to validate the asthma risk grid proposed and illustrated by Klein et al. (2004), demonstrating its association with relevant outcomes. Following its validation, employing the grid in research paradigms to assess accuracy in asthma and evaluating its utility in clinical practice are promising directions.

**Recommendations for Applying Perceptual Accuracy in Clinical Practice**

Physicians should be educated about the propensity of patients to make perceptual errors and the implications such errors have for self-management. The key application of perceptual accuracy to clinical practice is the identification of inaccurate patients and subsequent intervention to improve their accuracy. Assessment of perceptual accuracy in clinical practice may also inform and facilitate medical management. For this to occur, assessment and interventions need to be of minimal burden to both physician and patient.

In endocrinology, physicians and diabetes educators should reconsider the practice of teaching classical signs of hypo- and hyperglycemia and instead adopt an individualized approach to symptoms predictive of hypo- and hyperglycemia. Patients with disorders 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 using objective self-measurement (Cox et al., 1989, 1991; Gonder-Frederick & Cox, 1986). This underscores the importance of assessing accuracy in clinical practice and intervening as needed; broadening the implementation of BGAT by diabetes educators may increase its application to more patients and assist in reducing errors.

In pulmonology, ability to identify accurate patients and those prone to clinically relevant errors may also facilitate an individualized approach to medical management. As Klein et al. (2004) suggest, those prone to estimates in the Danger zone can be educated about their individually predictive symptoms, the danger of relying on their subjective sense of pulmonary functioning, and the need to rely on regular peak flow monitoring regardless of symptoms. Those making symptom magnification errors can be informed of which symptoms actually predict their functioning and which do not, and they can be assisted in differentiating asthma-related physiological sensations from those that are unrelated (Klein et al., 2004).
Based on Wamboldt's (1998) pilot data, accurate perceivers may need rationale for the importance of prophylactic medications such as inhaled steroids. Further, for accurate individuals, symptom-based action plans may be appropriate. In one sample of adults with asthma who were not poor perceivers of bronchoconstriction, peak flow monitoring action plans were equivalent to symptom-based action plans with respect to appropriate use of the plan and morbidity variables (Adams, Boath, Homan, Campbell, & Ruffin, 2001). Although the National Heart, Lung, and Blood Institute (NHLBI) recommends designing pediatric self-management plans on the basis of peak flow measurement, patient adherence to meter use is often low and measurement may only occur at best 2–3 times per day (Reeder et al., 1990; Sly, 1996). Therefore, if accurate patients can be identified and trained to use symptom-based plans, they could be considerably more practical.

Conclusions

Children and adolescents with asthma or diabetes evidence considerable variability in perceptual accuracy and frequently make clinically relevant perceptual errors that have the potential to affect self-management behavior. The science of perceptual accuracy can be promoted by studying distinct types of perceptual errors in addition to global perceptual accuracy, empirically supporting the relationship between symptom perception and self-management behavior, identifying factors related to perceptual inaccuracy, and conducting longitudinal research and intervention studies. Application of the construct in clinical practice may identify patients in need of intervention and facilitate both self- and medical management.

Received September 14, 2004; revision received November 10, 2004; accepted January 31, 2005

References


