

# Blood Glucose Awareness Training: What Is It, Where Is It, and Where Is It Going?

Daniel J. Cox, PhD, ABPP; Linda Gonder-Frederick, PhD; Lee Ritterband, PhD; Kushal Patel, PhD; Hartmut Schächinger, MD; Gabriele Fehm-Wolfsdorf, PhD; Norbert Hermanns, PhD; Frank Snoek, PhD; John Zrebiec, MSW, CDE; William Polonsky, PhD, CDE; David Schlundt, PhD; Boris Kovatchev, PhD; and William Clarke, MD

## Abstract

Management of type 1 diabetes requires a continual balancing of insulin, fuel intake, and metabolic demand (e.g., exercise). This can only be accomplished with knowledge of where one's blood glucose is and where it is going and knowledge of how to manipulate insulin, fuel, and exercise to manage it. Blood Glucose Awareness Training (BGAT) is a psychoeducational intervention that in part addresses these needs. Fifteen research studies from the United States and Europe, involving single-

site and multicenter projects, are reviewed. BGAT has been consistently demonstrated to improve the ability to detect and diminish both hypoglycemia and hyperglycemia while reducing the sequelae of extreme blood glucose levels (e.g., episodes of severe hypoglycemia and driving mishaps). BGAT has recently been transformed for internet delivery, making it available both for clinicians to use with their patients and for individuals with type 1 diabetes to pursue as a self-directed tutorial.

The management of diabetes is a balancing act. For individuals with type 1 diabetes, it is like balancing a three-armed teeter-totter, with one arm supporting fuel consumption (e.g., food), a second supporting metabolic demand (e.g., physical activity), and a third supporting insulin. If there is relatively too much insulin, the teeter-totter tips into hypoglycemia, exposing the individual to unpleasant counterregulation symptoms,<sup>1</sup> the impact of neuroglycopenia disrupting performance of routine tasks,<sup>2</sup> and even death as in the case of the dead-in-bed phenomenon.<sup>3</sup> Conversely, if the imbalance is in the direction of a relative lack of insulin in relation to metabolic demands for it, the teeter-totter will tip toward hyperglycemia and the short-term negative effects of cognitive dysfunction,<sup>4</sup> lethargy,<sup>4,5</sup> diabetic ketoacidosis,<sup>6</sup> and possible chronic complications such as cardiovascular disease.<sup>7</sup>

Although health care providers can write insulin prescriptions and dietitians and diabetes educators can make recommendations about nutrient intake and exercise on a periodic basis, it is left to patients to make hourly, weekly, and lifelong decisions

that lead to balance or imbalance of metabolic control. These decisions are made more difficult by the fact that these three elements and other unknown factors are dynamic and interacting. One must consider the dose, timing, and type of insulin; duration and intensity of physical activity; and amount and type of food consumption to correct extreme blood glucose or maintain euglycemia. However, because the management of diabetes is only secondary to engaging in an active occupational, social, family, and personal life, this balancing must be done as a secondary process.

**Blood Glucose Awareness Training** Blood Glucose Awareness Training (BGAT) is a psychoeducational intervention designed to assist individuals with type 1 diabetes in this continual balancing process. To effectively manage diabetes, individuals need accurate information about how their insulin, dietary choices, and physical activity levels impact their blood glucose. Additionally, to manipulate these exogenous factors to achieve euglycemic balance, patients need to know where their blood glucose is and where it is going. For example, a

Address correspondence to Daniel J. Cox, PhD, Center for Behavioral Medicine Research, Box 800223, University of Virginia Health System, Charlottesville, VA 22908.

blood glucose level of 60 mg/dl that is rising may need no intervention, whereas a blood glucose level of 65 mg/dl that is falling requires immediate consumption of fast-acting carbohydrates and no intense physical activity. Furthermore, individuals need to know how to use blood glucose feedback to achieve the desired balance. One way of empowering patients with such information and skills is through BGAT.<sup>8</sup> The purpose of BGAT is to improve individuals' ability to detect, anticipate, avoid, and treat extremes in blood glucose levels.

BGAT is an 8-week psychoeducational training program with the goals of improving individuals' ability to: 1) anticipate extreme blood glucose levels, 2) detect the presence of extreme blood glucose levels, 3) treat current extreme blood glucose levels, and 4) prevent future extreme blood glucose levels. The training program follows an eight-chapter manual that includes didactic information, self-assessment tools, and active learning exercises. Unit 1 focuses on how to apply the content of BGAT to daily life through homework, including making use of blood glucose awareness diaries and plotting blood glucose estimates on an error grid.<sup>9</sup> The blood glucose awareness diary involves users observing and recording any blood glucose-relevant cues, estimating their blood glucose level based on these cues, comparing their estimate to the current self-monitoring of blood glucose (SMBG) reading, and then evaluating the accuracy of their estimate using an error grid. This process is repeated throughout BGAT, with emphases on different cues as patients progress through different units, progressively refining their blood glucose estimation accuracy.

Units 2–4 focus on the interpretation of exogenous or external cues (carbohydrate counting, insulin kinetics, and metabolic equivalents of physical activity) to better understand why blood glucose is where it is and what changes are likely to occur in the future. The emphasis is on improving patients' ability to identify mismatches in these three critical aspects of self-management that lead to blood glucose extremes.

Units 5–7 teach users about symptoms or internal cues (e.g., autonomic, neuroglycopenic, and mood symptoms) so they can better recognize and

interpret symptoms of extreme blood glucose to improve detection of these events. Unit 8 summarizes what has been learned from the previous 7 weeks of training and promotes relapse prevention. The manual for the second version of BGAT (BGAT-2) is written in English and has also been translated into German,<sup>10</sup> Dutch,<sup>11</sup> and Japanese.<sup>12</sup>

### Efficacy of BGAT

BGAT is one of the most well-documented training programs for adults with type 1 diabetes. The theoretical mechanisms of BGAT have been thoroughly detailed by Gonder-Frederick et al.<sup>8</sup> Various research designs, dependent variables, and research centers have collectively and consistently demonstrated the benefits of BGAT. (Table 1).

The first randomized clinical trial by Cox et al.<sup>13</sup> investigated whether the first version of BGAT-1 improved accuracy of blood glucose estimates. Twenty subjects with type 1 diabetes were randomly assigned to BGAT-1 or an active control group (stress management). The results indicated that BGAT-1 significantly improved participants' pre- to posttreatment blood glucose estimation accuracy and detection of hypoglycemia relative to control subjects.

A second randomized clinical trial by Cox et al.<sup>14</sup> investigated the impact of BGAT-1 on blood glucose estimates and metabolic control. A total of 22 subjects with type 1 diabetes were randomly assigned to BGAT-1 or a control group. The results of this trial replicated the improvement in blood glucose estimation accuracy seen in the first clinical trial. BGAT-1 also improved participants' hemoglobin<sub>A1</sub> (Hb<sub>A1</sub>) compared to controls. Posttreatment improvements were associated with baseline blood glucose estimation accuracy, with less-accurate subjects demonstrating the greatest improvements.

A follow-up study<sup>15</sup> investigated whether individuals who received BGAT-1 ~ 4.9 years earlier exhibited continued benefits in terms of blood glucose estimation accuracy, fewer motor vehicular collisions, and fewer episodes of severe hypoglycemia compared to control subjects. Additionally, half of the BGAT subjects received booster training involving completion of blood glucose diaries and error grids

for 2 weeks. The results indicated that BGAT-1 significantly reduced the number of motor vehicular collisions and reduced the number of severe hypoglycemic episodes. Also, participants who received booster training estimated their blood glucose levels with significantly greater accuracy and were more aware of their hypoglycemia.

A third randomized study<sup>16</sup> investigating the differences between standard and intensive BGAT indicated that both led to improved blood glucose estimation accuracy. Intensive training involved hospitalizing subjects, manipulating their blood glucose into hypo- and hyperglycemic ranges, having patients estimate the blood glucose, and then providing immediate feedback and symptom review. Although both led to improved blood glucose estimation accuracy, only subjects who received intensive BGAT-1 demonstrated a significant improvement in metabolic control as measured by Hb<sub>A1</sub>.

Kinsley et al.<sup>17</sup> randomly assigned 47 subjects with uncomplicated type 1 diabetes who were undergoing intensive insulin therapy to receive either BGAT-1 or an education control group. This study demonstrated that the counterregulatory epinephrine response to hypoglycemia was preserved in the BGAT-1 group, whereas control subjects demonstrated a loss of hormonal counterregulation with improved metabolic control. These results suggested that BGAT-1 may be a useful intervention to decrease blunting of counterregulatory responses to hypoglycemia, possibly through avoidance of frequent low blood glucose.

Nurick and Johnson<sup>18</sup> provided BGAT-1 to a group of young adult outpatients and a group of adolescent inpatients with type 1 diabetes. The results indicated that, compared to the control group, BGAT-1 subjects significantly improved their blood glucose estimation accuracy; specifically, they had greater awareness of hypo- and hyperglycemia.

Broers et al.<sup>11</sup> hypothesized that BGAT administered individually would be more effective than when delivered in the traditional group format. There was no difference between individually and group-administered BGAT-1. Although BGAT-1 marginally improved blood glucose estimation accuracy, it did

**Table 1. Pre-Post Efficacy of BGAT and HAATT**

Study	Design	Multicenter	n	% Improvement in Recognition of Blood Glucose Levels						% Improvement in Judgement		% Reduction in Negative Consequences		
				Accuracy Index	Detection of Low Blood Glucose	Detection of High Blood Glucose	BGRI	LBGI	HBGI	Decision not to Drive When Blood Glucose Is Low	Decision to Treat When Low	Driving Mishaps	Episodes of Severe Hypoglycemia	Fear of Hypoglycemia
Schachinger <sup>24</sup>	Randomized Control	Y	111	16	10	18	NR	17	-2	NR	NR	NR	92	8
12-month follow-up <sup>24</sup>	Randomized Control	Y	111	22	24	19	NR	13	4	NR	NR	NR	91	20
Broers et al., 2005, <sup>19†</sup>	Repeated Baseline	N	59	259	51	15	3	11	8	33	25	68	79	6
Fehm-Wolfsdorf and Peters, 2005 <sup>10</sup>	Repeated Baseline	Y	309	NR	NR	NR	NR	NR	NR	NR	NR	Too rare	NR	19
Cox et al., 2004 <sup>30</sup>	Randomized Control	Y	60	17	35	NR	17	28	13	NR	22	NR	80	NR
Broers et al., 2002 <sup>11</sup>	Repeated Baseline	N	59	60	22	5	2	8	1	18	15	NR	NR	NR
Cox et al., 2001 <sup>29</sup>	Randomized Control	Y	64	14	15	NR	NR	12	4	10	36	86	57	17
Cox et al., 2001 <sup>23</sup>	Randomized Control	Y	73	21	29	4	7	NR	NR	6	16	68	31	21
Cox et al., 1994 <sup>15</sup>	Randomized Control	N	41	NR	NR	NR	NR	NR	NR	NR	NR	65	NR	NR
Cox et al., 1991 <sup>16</sup>	Randomized Control	N	39	37	23	58	NR	NR	NR	NR	NR	NR	NR	NR
Cox et al., 1989 <sup>14</sup>	Randomized Control	N	22	46	48	68	NR	NR	NR	NR	NR	NR	NR	NR
Cox et al., 1988 <sup>13</sup>	Repeated Baseline	N	16	23	*	NR	NR	NR	NR	NR	NR	NR	NR	NR
Cox et al., 1988 <sup>13</sup>	Repeated Baseline	N	20	20	*	NR	NR	NR	NR	NR	NR	NR	NR	NR

NR = Not reported.

BGRI = Blood Glucose Risk Index.

LBGI = Low Blood Glucose Risk Index.

HBGI = High Blood Glucose Risk Index.

\* = Significant effect but no data to calculate pre-post percentage improvement for blood glucose.

† = Only information about BGAT delivered in group format is provided.

lead to significantly better judgment in deciding whether to drive when blood glucose was low. It is not clear whether this minimal effect was because of cross-cultural issues related to the fact that the U.S. BGAT-1 was employed in the Netherlands or because of the relatively small sampling of blood glucose estimates.

However, a 1-year follow-up by Broers et al.<sup>19</sup> demonstrated that the Dutch BGAT-1 significantly improved recognition of hypoglycemic episodes, improved decisions not to drive during hypoglycemia, improved decisions to raise low blood glucose, and significantly reduced both the occurrence of severe hypoglycemic episodes and vehicular collisions. Also, the accuracy of blood glucose estimations significantly improved only for subjects who had received BGAT-1 in the conventional group format compared to an individual format.

Because of the highly specific benefits of BGAT-1 in terms of improving awareness of extreme blood glucose levels, it has recently been used as a comparison group to another intervention with other specific end points. van der Ven et al.<sup>20</sup> have compared BGAT-1 to a treatment intervention designed to improve coping with diabetes by means of cognitive behavior group therapy (CBGT). They found that BGAT-1 compared to CBGT at 3 months follow-up resulted in equally favorable psychological outcomes in terms of reduced emotional distress and improved diabetes self-efficacy.<sup>21</sup> At 1 year follow-up, they found similar results, but BGAT-1 proved less effective than CBGT in reducing hemoglobin A<sub>1c</sub> (A1C) in participants who reported higher levels of depressive symptoms at baseline (NCW van der Ven, J Twisk, MHE Hogenelst, AME Tromp-Wever, HM van der Ploeg, RJ Heine, FJ Snoek, unpublished observations).

### Multicenter Trials

Several large multicenter studies have confirmed the effectiveness of BGAT-2 in improving blood glucose estimation accuracy and diminishing occurrence and sequelae of hypo- and hyperglycemia. Cox et al.<sup>22,23</sup> administered BGAT-2 to 73 adults with type 1 diabetes recruited from Vanderbilt University (Nashville, Tenn.), the Joslin Diabetes Center (Boston,

Mass.), and the University of Virginia (central Virginia), employing a 6-month repeated baseline and 12-month follow-up design. Throughout baseline and follow-up, participants were assessed for occurrence of extreme blood glucose, detection/recognition of extreme blood glucose, sequelae of extreme blood glucose, and psychological functioning. Although the repeated baseline design demonstrated that none of the outcome variables changed as a function of time over the baseline, throughout the 12-month follow-up, participants demonstrated 1) improved detection of low blood glucose, 2) reduced frequency of extreme blood glucose, 3) reduced consequences of extreme blood glucose (diabetic ketoacidosis, severe hypoglycemia, and moving vehicle violations), and 4) improved psychological functioning (less fear of hypoglycemia, less depressive symptoms for those patients who were depressed, improved diabetes quality of life, and improved diabetes knowledge).

A multicenter study conducted in Switzerland and Germany by Schächinger et al.<sup>24</sup> showed similar improvements for people with type 1 diabetes using BGAT-2. The authors performed a similar 6-month baseline and 12-month follow-up study of 111 adults with type 1 diabetes randomized to either BGAT-2 or a physician-guided self-help control intervention. At 12-months' follow-up, BGAT-2 participants were significantly better than control subjects in terms of: 1) improved detection of hypoglycemia and hyperglycemia, 2) reduced occurrence of severe hypoglycemia, 3) improved estimation of current blood glucose, and 4) improved psychological functioning (less fear of hypoglycemia, internalized locus of control, and improved diabetes knowledge).

An effectiveness study in Germany<sup>25</sup> included > 300 patients who were trained by 50 BGAT trainers in their local medical setting. Pre- and posttraining assessments revealed significant improvements in 1) detection of hypo- and hyperglycemia, 2) A1C, and 3) psychological functioning (Beck Depression Inventory scores, fear of hypoglycemia, quality of life, and internalized locus of control). A 12-month follow-up is underway.

### Hypoglycemia Anticipation, Awareness, and Treatment Training

Given that hypoglycemia has been considered the major barrier to intensive insulin therapy,<sup>26</sup> and given that BGAT has significantly improved hypoglycemic parameters, researchers at the University of Virginia developed a treatment program that was similar to BGAT but focused specifically on hypoglycemia for individuals suffering from recurrent severe hypoglycemia. First, they developed a biopsychobehavioral model of risk for severe hypoglycemia,<sup>27</sup> which they later validated.<sup>28</sup> This model presumes that there are eight elements to the occurrence of severe hypoglycemic events: 1) predisposing factors that increase the risk for low blood glucose, 2) an actual low blood glucose event, 3) failure to counterregulate, 4) absence of hypoglycemic symptoms, 5) failure to detect hypoglycemia, 6) failure to judge when self-treatment is needed, 7) inadequate self-treatment to reverse low blood glucose, and then 8) severe hypoglycemia (neuroglycopenia that precludes self-treatment).

The University of Virginia team subsequently developed Hypoglycemia Anticipation, Awareness, and Treatment Training (HAATT), an eight-session psychoeducational program that focused on each of these eight steps. Two multicenter randomized clinical trials, including a 6-month baseline and 12-month follow-up, comparing HAATT and a control group have been conducted, one in the United States and one in Europe. The U.S. multicenter study involved 64 adults with type 1 diabetes from Boston or central Virginia, with a recent history of recurrent severe hypoglycemia. Subjects were randomized to either HAATT or empowerment training.<sup>29</sup> HAATT led to significant improvements in detection of low blood glucose, as well as a reduction in occurrence of low blood glucose events, severe hypoglycemia, and moving vehicular violations.

The European multicenter study involved 60 adults with type 1 diabetes who had a recent history of recurrent severe hypoglycemia. Subjects were recruited from three Bulgarian cities (Sofia, Russe, and Varna) and were randomized to SMBG (unavailable for routine care at the time) or SMBG plus HAATT.<sup>30</sup> During follow-up, HAATT led to sig-

nificantly greater improvement in detection and treatment of hypoglycemia, reduction in occurrence of hypoglycemia, and fewer waking and nocturnal episodes of severe and moderate hypoglycemia. The improvements achieved by HAATT in treatment, detection, and occurrence of hypoglycemia were realized without compromising metabolic control. These benefits were maintained at 18 months' follow-up.

**BGATHome.com**

Although HAATT was effective in reducing occurrence of low blood glu-

cose and severe hypoglycemia, its 84% reduction in such events was not substantially better than the 75% reduction achieved by BGAT-2. Consequently, it did not seem prudent to promote two separate but similarly effective psychoeducational programs. Instead, researchers consolidated the unique elements of BGAT-2 and HAATT into a third edition of BGAT.

A major barrier to the dissemination of BGAT's positive benefits was availability of training and materials. In order to maximize distribution and minimize costs, researchers secured a grant from the American Diabetes

Association to operationalize BGAT and transform it for delivery on the internet as BGATHome.com. This program has an introduction and seven subsequent units (Table 2). Each unit requires between 15 and 60 minutes to complete. It is an interactive system, in which users enter personal data, such as their insulin regimen or the results from their blood glucose awareness diary. Using this information, the system provides personalized feedback, such as an insulin action curve or identification of optimally discriminating symptoms of hyperglycemia and hypoglycemia.

**Table 2. Content of BGATHome.com**

Unit	Estimated Minutes to Complete; Range (Mean)	Content
Introduction	5–10	The objectives and process of BGAT are reviewed, the role of extreme blood glucose and possible concurrent cues are discussed, and individuals set personal goals for BGAT. In this and all other units, there is extensive use of case studies and interaction exercises in which the user enters personal information.
1 Blood glucose diaries	15–20 (16.7)	Individuals learn about and personally apply information concerning internal and external cues of extreme blood glucose, how to scan for and become sensitive to such cues, and how to use this information to estimate current and anticipate future blood glucose. This is recorded in blood glucose diaries whenever they perform SMBG, and they learn how to plot this blood glucose estimate on an error grid to interpret the estimation error/accuracy. This and all subsequent units conclude with a self-test relevant to the content of the unit and specific homework exercises to help personalize the material.
2 Insulin kinetics	25–40 (20.5)	This unit, and all subsequent units, begins with individuals completing a summary sheet on which they enter data concerning their extreme blood glucose levels abstracted from the blood glucose diary. Individuals then learn about and personally apply information concerning insulin kinetics and enter their own insulin regimen into a plotting program that displays its blood glucose-lowering potential, identifying when their blood glucose is most likely to be low or high. There are separate elements for those using insulin injections and insulin pumps.
3 Nutrients	30–50 (40.4)	Individuals learn about and personally apply information concerning carbohydrate counting, role of protein and fat, and how to anticipate the time course and degree their nutrient intake may have on their blood glucose. Insulin and food curves are plotted, and individuals learn how to match their food intake with their insulin action.
4 Physical activity	20–35 (26.2)	Individuals learn about and personally apply information regarding metabolic equivalent of different physical activities and how this can affect blood glucose when considering their insulin profile and nutrient intake.
5 Symptoms	35–50 (38.5)	Individuals learn about and personally apply information concerning how extreme blood glucose can affect physical and emotional symptoms, how to better recognize and interpret such blood glucose cues, and when to look for these cues, given their recent insulin, food, and exercise. Emphasis is placed on how changes in mood can affect interpersonal relationships.
6 Cognitive-motor function	10–25 (15.2)	Individuals learn about and personally apply information concerning the effects of extreme blood glucose on cognitive and motor functioning and how to recognize and interpret such cues. Emphasis is placed on how such disruptions can affect job and driving performance.
7 Summary	15–30 (18)	Individuals review what has been learned in the previous units, receive feedback in terms of shifts in estimation accuracy and blood glucose distributions, and identify their most reliable symptoms of hypo- and hyperglycemia. Individuals set personal goals, and relapse prevention is reviewed.

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BGATHome.com is a linear program, in which users must complete the introduction before proceeding to Unit 1, or complete Unit 1 before proceeding to Unit 2. There must be at least 7 days of blood glucose diaries before proceeding to the subsequent unit. Although BGATHome can be used in a traditional group format led by a diabetes expert, it can also be used as a self-directed tutorial program. Regardless of how BGATHome.com is implemented, users are issued a personalized certificate of completion if the entire program is completed within 12 weeks. Such certifications may be useful for insurance companies or court systems who want some documentation that individuals have taken steps to improve their blood glucose management.

How attractive is BGAT delivered over the internet? The team placed a one-page notice in *Diabetes Forecast* magazine describing a study being conducted on BGATHome.com. Within 1 week after the publication of this notice, hundreds of individuals from the United States and other countries went to the website and completed the application to participate in the study, at which time the team had to close registration. This suggests that there is a real desire and need for BGAT and that it is likely to be widely utilized by patients.

### Summary and Future Directions

The Diabetes Control and Complications Trial<sup>31</sup> highlighted the benefits of intensive insulin therapy and the importance of behavioral factors in helping people with diabetes adhere to more intensive and demanding regimens. Given the contributions of behavioral factors to diabetes self-management, BGAT can play a significant role in helping people with diabetes manage the continual balancing process of fuel consumption, insulin intake, and energy expenditure.

Overall, BGAT is a well documented psychoeducational program that offers several benefits for people with type 1 diabetes. Its benefits have been consistently empirically validated and include 1) improved accuracy of blood glucose estimations, 2) improved detection of hypoglycemia and hyperglycemia, 3) improved judgments related to decisions to self-treat when

blood glucose is low, 4) reduction in motor vehicular mishaps across time, 5) reduction in episodes of severe hypoglycemia, and 6) reduction in fear associated with hypoglycemia, while improving diabetic knowledge and quality of life.

A future direction for BGAT is dissemination of BGATHome.com. This internet version was designed to make BGAT more accessible and to make its benefits available to anyone with type 1 diabetes who has access to the internet. The philosophical basis of this version is to provide maximum distribution at minimum cost.

Individuals with type 2 diabetes represent ~ 90% of the diabetic population. Another future direction for BGAT is to adapt it for use with type 2 diabetes. We know that parents and children with type 1 diabetes are very inaccurate at estimating blood glucose levels and detecting hypoglycemia.<sup>32</sup> With National Institutes of Health funding, Dr. Gonder-Frederick is developing a version of BGAT for parents and their children. Finally, future research in BGAT needs to focus on examining whether it is beneficial across cultural and racial groups. Thus far, BGAT has been tested primarily on Caucasian populations from Europe and the United States. It is important to investigate whether the effects of BGAT generalize across racial and cultural groups.

### Acknowledgments

This research was supported by National Institutes of Health Grant DK28288 and a grant from the American Diabetes Association. The authors express their appreciation for BGAT leaders Karin Hegar from Basel, and Katja van Vliet, Sandra Broers Leiden, Nicole Van der Ven, and Frank Snoek from The Netherlands.

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*Daniel J. Cox, PhD, ABPP, and William Clarke, MD, are professors; Linda Gonder-Frederick, PhD, Lee Ritterband, PhD, and Boris Kovatchev, PhD, are associate professors; and Kushal Patel, PhD, is a post-doctoral fellow at the University of Virginia Health System in Charlottesville, Va. Hartmut Schächinger, MD, is a professor at the Graduate School of Psychobiology, University of Trier, Germany. Gabriele Fehm-Wolfsdorf, PhD, is a professor at the University of Luebeck, Germany. Norbert Hermanns, PhD, is head of the Research Institute of the Diabetes Academy, Mergentheim, Germany. Frank Snoek, PhD, is a professor at the Vrije Universiteit Medical Centre in Amsterdam. John Zrebiec, MSW, is a lecturer in psychiatry at Harvard Medical School in Boston, Mass. William Polonsky, PhD, CDE, is an associate clinical professor at the University of California, San Diego. David Schlundt, PhD, is an associate professor at Vanderbilt University in Nashville, Tenn.*