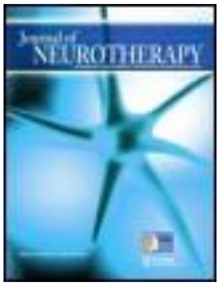

Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience

Neurofeedback Training in a Case of Attention Deficit Hyperactivity Disorder

Sonia Wadhwani [a], Diane C. Radvanski [a] & Dennis P. Carmody [a]

[a] Department of Psychology, 2641 John F. Kennedy Blvd., Jersey City, New Jersey, 07306, USA

Published online: 20 Oct 2008.

To cite this article: Sonia Wadhwani , Diane C. Radvanski & Dennis P. Carmody (1998) NEUROFEEDBACK TRAINING IN A CASE OF ATTENTION DEFICIT HYPERACTIVITY DISORDER, Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience, 3:1, 42-49, DOI: 10.1300/J184v03n01_05

To link to this article: http://dx.doi.org/10.1300/J184v03n01_05

NEUROFEEDBACK TRAINING IN A CASE OF ATTENTION DEFICIT HYPERACTIVITY DISORDER

Sonia Wadhwani, Diane C. Radvanski, Dennis P. Carmody

Saint Peter's College, Department of Psychology, 2641 John F. Kennedy Blvd., Jersey City, New Jersey 07306, 201-915-9418 phone, 201-332-7826 Fax, Email:, carmody_d@spcvxa. spc.edu

Portions of this research were supported by a Faculty-Student research grant awarded by Saint Peter's College. Portions of this research were presented at the meetings of the American Psychological Association, August 1997, Chicago. Details concerning the neurofeedback training are available from Dr. Mary Jo Sabo, Biofeedback Consultants Incorporated, Spring Valley, New York.

Electroencephalographic biofeedback, also known as neurofeedback, has been used to improve attention in children with Attention Deficit Hyperactivity Disorder (ADHD). In the present case study, a ten-year-old boy completed 37 sessions of neurofeedback training over a six-month period on-site in a school setting. Beta brainwave training was applied for sessions 1 - 22 and replaced by sensorimotor rhythm training for sessions 23 - 37. A review of his national achievement test scores for four years revealed he improved performance the year he received neurofeedback and the gain was lost the year after treatment was completed. The participant had been receiving methylphenidate for the previous two years and remained on the medication throughout neurofeedback and for the year after neurofeedback treatment. Findings are suggestive of the advantages of incorporating neurofeedback training as part of a multimodal treatment program in a school setting for children with ADHD.

Neurofeedback Training In A Case Of Attention Deficit Hyperactivity Disorder

Attention deficit hyperactivity disorder (ADHD) is a broadly defined set of behaviors and cognitive dysfunctions that affect individuals in the family, social and academic environments. Descriptions of the disorder have been offered for parents, educational systems, and health care professionals. Parents, family members, or teachers usually identify behaviors as deviant before formal diagnoses are made. Deviant motor overactivity includes fidgeting with hands and feet and difficulty remaining seated, while poor concentration, distractibility, and forgetfulness are deviant behaviors that are suggestive of inattention. Standardized inventories of motor activity and attentional ability have been developed to quantify the behaviors of children at home (Conners, 1989a) and school (Conners, 1989b; McCarney, 1992). The standard used by health care professionals is available in the Diagnostic and Statistical Manual (American Psychiatric Association, 1994) where ADHD is described according to specific forms and quantities of inattention and hyperactivity-impulsivity.

Interventions used to alter deviant behavior and inattention have included medication (Abikoff & Gittelman, 1985; Conners & Taylor, 1980), behavior modification (Heins, Lloyd, & Hallahan, 1986; Rapport, Murphy, & Bailey, 1990), and nutritional restrictions (Milich & Pelham, 1986; National Institute of Health, 1982). As early as 1937, Bradley reported the use of Benzedrine sulfate as a stimulant that was shown to improve school performance in children with behavioral problems. Behavior modification, or a token economy, has provided children with ADHD a form of structure and reward for desirable behavior (Moss & Dunlap, 1990). Methylphenidate treatment has been shown to improve abnormal EEGs in hyperactive children (Satterfield, Cantwell, Saul, Lesser, & Podosin, 1973) and to raise basal skin conductance in a group of hyperkinetic children to the levels of normal children (Satterfield & Dawson, 1971). Several reports have expressed concern about the overuse of methylphenidate in school populations. For example, Walker (1975) estimated that approximately 10-15% of students in some school districts were prescribed medications for hyperactivity. More recently, estimates indicated that 88% of children with ADHD received medications at some point in childhood (Wolraich, Lindgren, Stromquist, Milich, Davis, & Watson, 1990). Finally, Greene and Barkley (1996) suggested that some 20-35% of children with ADHD might not respond significantly to medication treatment.

Electromyography (EMG) and electroencephalography (EEG) are biofeedback modalities used to reduce motor activity and inattention. EMG biofeedback was used in a case of a six-year-old diagnosed as hyperactive by a learning disability center (Braud, Lupin, & Braud, 1975). A total of eleven sessions of EMG biofeedback of the frontalis muscle led to several significant changes. First, muscle tension declined both within and between sessions. Behavioral ratings showed a reduction in levels of activity, tension, and emotionality. Teacher observations in school and parent observations in the home noted improvements in overall functioning. Carter and Russell (1985) utilized EMG biofeedback with children with learning disabilities in a clinical setting to reduce excessive motor activities. Several positive findings included improvements in auditory memory, reading, and handwriting and drawing abilities. The authors attributed improvements to the EMG and relaxation interventions. Similar results, although of lower magnitude, were obtained in a second study conducted in a school setting (Carter & Russell, 1985).

As early as 1938, Jasper, Solomon, and Bradley described how the EEG analyses of the brainwaves were categorized as abnormal in seventy percent of children with behavior problems. In general, the EEG records the amplitude of brainwaves at each of a number of frequency bandwidths at various locations on the head, also known as the 10-20 international system of electrode placement (Satterfield, Cantwell, Saul, Lesser, & Podosin, 1973). The degree of attentional focus is interpreted from the amplitude of activity in different bandwidths. For example, an overabundance of theta waves suggests a daydreaming state (Green, Green & Walters, 1970) accompanied by a lack of attentional focus. A shortage of beta waves indicates a short concentration span (Lubar, 1991). Increased beta activity is associated with analytical and sequential cognitive activity (Lubar, 1997). Elevated theta/beta, or theta/SMR, ratios correlate empirically with the presence of ADHD symptoms, while reduced theta/beta, or theta/SMR, ratios correlate with the resolution of the symptoms (Abarbanel, 1995).

Several authors have described biofeedback training of brainwaves, also known as neurofeedback. In 1976, Lubar and Shouse utilized biofeedback to modify EEG performance and reduce excessive motor behaviors in an eleven-year-old hyperkinetic boy taking methylphenidate. The specific protocol included attempts to increase Sensorimotor Rhythm (SMR), a selected range of low beta typically within 12-15 Hz, that is considered to be instrumental in improving relaxed attention. Lubar and Shouse conducted the study in a laboratory setting where the child was trained for more than 150 sessions over several months. The goal was to reduce slow theta brainwave activity (4 to 7 Hz) and to increase SMR production. Results indicated that reductions in EMG were accompanied by increases in SMR over the first 60 sessions. The study was expanded to a total of four cases (Lubar & Shouse, 1977). When the protocol was reversed, leading to an inhibition of beta activity and an increase in theta activity, school performance deteriorated with a return to the former hyperactive behaviors. When the original protocol was reinstated to inhibit theta and increase beta, social behaviors and school performance were improved. Long term follow-up of the case study revealed sustained school performance.

A ten-year-old hyperactive boy was treated with EMG biofeedback and EEG neurofeedback (Tansey & Bruner, 1983). The boy received 40-minute EMG training sessions once a week for three weeks to train muscle relaxation. After baseline EMG training sessions, the boy was rewarded when he produced the target amplitude of SMR (12-14 Hz) for 20 sessions of EEG biofeedback. By the end of treatment, the participant reduced muscle tension, produced a greater abundance of SMR, and improved his reading and comprehension skills. At 24-month follow-up, he maintained his attentional abilities and academic achievements long after the biofeedback was terminated, and at ten-year follow-up, he showed sustained academic achievement (Tansey, 1993).

In a clinical setting, six children with learning problems were treated with long term EEG biofeedback twice a week for 27 months (Lubar & Lubar, 1984). Protocols included increasing SMR (12-15 Hz) or increasing beta activity (16-20 Hz). Results indicated that all participants decreased slow EEG (theta, 4-8 Hz), decreased EMG activity, and improved their acquisition of SMR and beta. Educational benefits were evident in improved grades and achievement test scores. Based on a continuous performance test, EEG biofeedback and stimulant medication were equally effective in the reduction of ADHD symptoms (Rossiter, & LaVaque, 1995). A report of large groups of adolescents and adults (Lubar, Swartwood, Swartwood & Timmermann, 1995), suggested that neurofeedback training lead to increased beta activity (13-21 Hz), reduced theta activity (4-8 Hz), and improved performance on continuous performance tasks. The parameter of theta/beta ratio was found to be higher among adolescents with attention deficit disorder than control adults. In a controlled study of outpatients at a mental health clinic ranging in age from 8-21 years, EEG biofeedback led to significant reduction in both cognitive and behavioral symptoms of ADHD after 20 treatment sessions over a period of four to seven weeks (Rossiter & LaVaque, 1985). An experimental study compared a waiting control group to an experimental group receiving training to enhance beta activity (16-20 Hz) and decrease theta activity (4-8 Hz) (Linden, Habib & Radojevic, 1996). The experimental group improved performance in attention, behavior and intellectual functioning. The authors have encouraged replications of their findings.

The purposes of the current study were first to assess the effectiveness of neurofeedback training conducted on site in a school setting over a sustained time period and second to examine the changes in theta and beta activity levels. Two protocols were attempted; the first protocol was designed to enhance beta (16-18 Hz) and reduce high delta-theta (2-7 Hz). The second protocol was designed to enhance SMR (13-15 Hz) and reduce delta-theta.

Methods

Participant

The single volunteer was a ten-year-old boy in the fifth grade. Based on his history of problems in the classroom including inattentiveness, impulsiveness, and hyperactivity, he met the DSM-IV criteria for Attention Deficit Hyperactivity Disorder (American Psychiatric Association, 1994). The vice-principal selected him as a candidate for the initial neurofeedback program at that school. Informed parental consent was obtained for his participation in the program, and the participant agreed to receive neurofeedback training. He had been treated with methylphenidate for the previous two years and he remained on the medication throughout the neurofeedback sessions.

Setting

The participant was a student at a public elementary school in an urban area in New York State. All neurofeedback sessions were conducted at the school in a room dedicated to training one participant alone for the neurofeedback project. The participant would be released for thirty minutes from standard classroom activities or recess to attend each session. A technician trained by Biofeedback Consultants Incorporated remained in the room during the sessions to ensure electrode placement, program initiation, and data collection.

Apparatus

Neurofeedback equipment included hardware and software supplied by the American Biotec Corporation. Hardware included three electrodes placed on the participant: A ground electrode was placed on the right ear, a reference electrode was placed on the left ear, and the active electrode was placed at C3 for a Beta protocol or at Cz for an SMR protocol. Impedance was measured prior to each session and maintained at less than 10K ohms to ensure good electrode-skin contact. The 2 to 7 Hz frequency bands (delta-theta) were selected as bands to be suppressed during neurofeedback. The 16 to 18 Hz frequency bands (beta) were selected as bands to be reinforced during neurofeedback for the first protocol. Both frequency bands were filtered and amplified through software, specifically a CapScan C-80 single channel amplifier. The amplified signals were sent to a 486 DX2/50 computer for visual and auditory feedback presentations to the participant. Prior to each session, a threshold for beta frequencies was set for reinforcement above which a high pitched tone would be heard sixty to seventy-five percent of the time. Likewise, a threshold was set for inhibition of delta-theta frequencies below which a low-pitched tone would be heard seventy-five to eighty-five percent of the time. A threshold for EMG activity, the 70 to 90 Hz range, was set for inhibition below which a midrange tone would be heard 60-75% of the time. When reinforcement and inhibition task criteria were simultaneously met, the participant received preferred visual feedback and auditory feedback tones. When criteria were not simultaneously met, feedback would cease.

Procedure

The participant completed 37 sessions of 30-minutes each from January through June 1996. For each session, he sat in a chair in front of the computer monitor, and a technician placed electrodes on his scalp and ears. Thresholds were adjusted from session to session in order to encourage higher levels of performance over the course of training. For each session, the participant viewed video programs such as an arcade-like game in which points would be accumulated within each session when the targeted delta-theta and beta levels were achieved. The average amplitudes of beta, delta-theta, and EMG activities were stored in the software every three minutes. Based on the assessment by the school psychologist, the participant was given a protocol initially designed to reduce depression. Therefore, for the first 22 sessions, beta activity (16-18 Hz) was reinforced. When the participant became agitated from the treatment, the protocol was changed to reinforce SMR activity (13-15 Hz) for sessions 23 through 40.

Results

Brainwave Activity

Several parameters of neural activity were examined, including delta-theta, beta, SMR and EMG and the derived parameters of the delta-theta/beta ratio and delta-theta/SMR ratio. Regression analyses were employed to determine systematic changes in the measures over sessions. Table 1 presents the correlation, slope, and intercept for these analyses. Delta-theta significantly increased during beta training, and then decreased during SMR training.

The average beta amplitude for the first five sessions was 4.14 microvolts and the average for the last five sessions was 4.76 microvolts indicating an increase of 15% in the average amplitude of beta waves, $t\,(98) = 2.38$, $p < .02$. SMR amplitudes decreased 29% from the first five sessions of SMR training (5.46 microvolts) to the last five sessions (3.89 microvolts), a significant change, $t\,(98) = 4.74$, $p < .001$. EMG significantly increased 11% over beta training and remained stable over SMR training. The delta-theta/beta ratio was unchanged over sessions while the delta-theta/SMR increased 39% over sessions from an average ratio of 4.53 to 6.29, $t\,(98) = 5.77$, $p < .001$.

Table 1
Regression Results

Parameter	Correlation with Sessions	Regression Slope	Regression Intercept
Delta-theta (Sessions 1-22)	0.238 **	0.152 **	20.58
Delta-theta (Sessions 23-37)	-0.114	-0.116	24.73
Beta (Sessions 1-22)	0.226 **	0.073 **	4.33
SMR (Sessions 23-37)	-0.330 **	-0.152 **	6.37
EMG (Sessions 1-22)	0.380 **	0.036 **	3.16
EMG (Sessions 23-37)	-0.145	-0.018	4.07
Delta-theta/Beta Ratio	-0.212 *	-0.043 *	5.22
Delta-theta/SMR Ratio	0.450 **	0.168 **	3.81

* $p < .01$
** $p < .001$

Achievement Tests

The results of national achievement tests were reviewed for the four school years ending 1994 to 1997. The district administered the Metropolitan Achievement Tests in May 1994 and May 1995, and the California Achievement Tests in June 1996 and June 1997. There are four dimensions common to the MAT and CAT: Vocabulary, Reading Comprehension, Math Comprehension, and Total Math Score. The grade equivalent scores for the four dimensions are shown in Table 2. Overall, the participant's performance relative to grade equivalence was 41% in 1994, 58% in 1995, 72% in 1996, and 35% in 1997. The highest equivalent performance was achieved in June 1996 corresponding to the last session of neurofeedback training.

Discussion

Neurofeedback training in this case study was successful in several dimensions. First, the training was found to be effective in a school setting with results similar to the findings from studies conducted in laboratory (Lubar & Shouse, 1976) and clinical settings (Lubar & Lubar, 1984; Rossiter & LaVaque, 1995). As indicated by Green and Barkley (1996), the necessity of focusing a majority of intervention efforts within traditional settings, such as a school, is crucial for achieving desired behaviors. Furthermore, the participant

Table 2
Performance on National Achievement Tests

Test Date	Normative Grade	Vocabulary - Grade Equivalent	Reading Comprehension - Grade Equivalent	Math Comprehension - Grade Equivalent	Total Math - Grade Equivalent	Performance Relative to Grade Equivalent
May 1994	1.7	0.9	1.4	0.1	0.4	0.41
May 1995	2.7	1.5	1.5	1.9	1.4	0.58
June 1996	3.8	2.3	2.5	3.2	3.0	0.72
June 1997	4.8	0.5	1.9	2.4	1.9	0.35

in this case study maintained interest and voluntary participation over a sustained time period of several months. This finding encourages the use of neurofeedback interventions in a school setting.

The second major finding was his improvement in performance on standardized achievement tests. The highest level of performance, 72% of grade equivalence, was achieved at the end of the neurofeedback training. Performance for the two years prior to training averaged 49% and performance the year after training was 35%. These changes are not attributed to the continued administration of methylphenidate since the participant was receiving medical treatment for the two years prior to the introduction of neurofeedback and remained medicated the year after training.

The effect of beta enhancement versus SMR enhancement cannot be compared directly. It would be necessary to maintain the beta enhancement protocol over a larger number of sessions to determine the effectiveness. For example, Lubar & Lubar (1984) provided sessions per week for ten to twenty-seven months. The ratio of theta to beta was noted to decrease with beta training and to increase with SMR training. Explanations for the discrepancy may be found in the conclusions reached by Lubar (1997). Lubar monitored EEG activity of participants while they listened to a story with vivid action scenes. He attributed the increases in theta activity (4 - 8 Hz) to the visualization of the scenes by the participants, and the increases in beta activity to analytical and sequential cognitive processes. The effect of the SMR training led to decreases both in SMR and in delta-theta. Therefore, the overall derived ratio of delta-theta/SMR significantly increased primarily due to the sharp reductions in SMR.

In conclusion, neurofeedback training was successfully applied on site in a school setting in this case study of attention deficit hyperactivity disorder. Genuine changes in brainwave activity and achievement performance were not attributed to medication or to a specialized clinical setting. The program was applied in conjunction with continued methylphenidate medication. Overall, the findings of the case study demonstrated that neurofeedback training was applied successfully in a school setting as part of the school program for a child with Attention Deficit Hyperactivity Disorder.

References

Abarbanel, A., (1995) Gates, states, rhythms, and resonances: the scientific basis of neurofeedback training. *Journal of Neurotherapy, 1(2),* 15-38.

Abikoff, H., & Gittelman, R. (1985). The normalizing effects of methylphenidate on the classroom behavior of ADHD children. *Journal of Abnormal Child Psychology, 13,* 33-44.

American Psychiatric Association. (1994). *Diagnostic and Statistical Manual IV (DSM-IV).* Washington, DC.

Bradley, C. (1937). The behavior of children receiving Benzedrine. *American Journal of Psychiatry, 94,* 577-585.

Braud, L. W., Lupin, M. N., and Braud, W. G. (1975). The use of electromyographic biofeedback in the control of hyperactivity. *Journal of Learning Disabilities, 8* (7), 420-425.

Carter, J. L. & Russell, H. L., (1985). Use of EMG biofeedback procedures with learning disabled children in a clinical setting. *Journal of Learning Disabilities, 18 (4),* 213-216.

Conners, C. K. (1989a). *Conners' Parent Rating Scales.* North Tonawanda, NY: Multi-Health Systems.

Conners, C. K. (1989b). *Conners' Teacher Rating Scales.* North Tonawanda, NY: Multi-Health Systems.

Conners, C. K., & Taylor, E. (1980). Pemoline, methylphenidate, and placebo in children with minimal brain dysfunction. *Archives of General Psychiatry, 37,* 922.

Green, E. E., Green, A.M., & Walters, E. D. (1970). Voluntary control of internal states: psychological and physiological. *Journal of Transpersonal Psychology, 2,* 1-26.

Greene, R. W., & Barkley, R. A. (1996). Attention deficit hyperactivity disorder: diagnostic, developmental, and conceptual Issues. In M. .J. Breen and C. R. Fiedler (Eds.) *Behavioral approach to assessment of youth with emotional/behavioral disorders*. Austin: Pro-Ed.

Heins, E. D., Lloyd, J. W., & Hallahan, D. P. (1986). Cued and non-cued self-recording of attention to task. *Behavior Modification, 10*, 235-254.

Jasper, H., Solomon, P., & Bradley, C. (1938). Electroencephalographic analyses of behavior problem Children. *American Journal of Psychiatry, 95*, 641-658.

Linden, M., Habib, T., & Radojevic, V. (1996). A controlled study of the effects of EEG biofeedback on cognition and behavior of children with attention deficit disorder and learning disabilities. *Biofeedback and Self-Regulation, 21*, 35-48.

Lubar, J. F. (1997). Neocortical dynamics: implications for understanding the role of neurofeedback and related techniques for the enhancement of attention. *Applied Psychophysiology and Biofeedback, 22*, 111-126.

Lubar, J. F. (1991). Discourse on the development of EEG diagnostics and biofeedback for attention-deficit/hyperactivity disorders. *Biofeedback and Self-Regulation, 16*, 201-225.

Lubar, J. O., & Lubar, J. F. (1984). Electroencephalographic biofeedback of SMR and beta for treatment of attentiondeficit disorders in a clinical setting. *Biofeedback and Self-Regulation, 9*, 1-23.

Lubar, J. F., & Shouse, M. N. (1976). EEG and behavioral changes in a hyperkinetic child concurrent with training of the sensorimotor rhythm (SMR): A preliminary report. *Biofeedback and Self-Regulation, 1*, 293-305.

Lubar, J. F., & Shouse, M. N. (1977). Use of biofeedback in the treatment of seizure disorders and hyperactivity. Advances in Child Clinical Psychology, 1, 204-251.

Lubar, J. F., Swartwood, M. O., Swartwood, J. N., & Timmermann, D. L. (1995). Quantitative EEG and auditory event-related potentials in the evaluation of attention-deficit/hyperactivity disorder: Effects of methylphenidate and implications for neurofeedback training. *Journal of Psychoeducational Assessment, ADHD Special*, 143-160.

McCarney, S. B. (1992). *Emotional or Behavior Disorder Scale*. Columbia, MO: Hawthorne Educational Services.

Milich, R., & Pelham, W. E. (1986). The effects of sugar ingestion on the classroom and playgroup behavior of attention deficit disordered boys. *Journal of Consulting and Clinical Psychology, 54*, 714-718.

Moss, R. A., & Dunlap, H. H. (1990). *Why Johnny Can't Concentrate: Coping With Attention Deficit Problems*. New York: Bantam Books.

National Institute of Health (1982). Defined diets and childhood hyperactivity: Consensus conference. *Journal of the American Medical Association, 248*, 290-292.

Rapport, M., Murphy, A., & Bailey, J. S. (1990). The effects of a response cost treatment tactic on hyperactive children. *Journal of School Psychology, 18*, 98.

Rossiter, T. R., & LaVaque, T. J. (1995). A comparison of EEG biofeedback and psychostimulants in treating attention deficit hyperactivity disorders. *Journal of Neurotherapy, 1 (Summer)*, 48-59.

Satterfield, J. H., Cantwell, D. P., Saul, R. E., Lesser, L. I., & Podosin, R. L. (1973). Response to stimulant drug treatment in hyperactive children: Prediction from EEG and neurological findings. *Journal of Autism and Childhood Schizophrenia, 3*, 36-48.

Satterfield, J. H., & Dawson, M. E. (1971). Electrodermal correlates of hyperactivity in children. *Psychophysiology, 8*, 191-197.

Tansey, M. A. (1993). Ten year stability of EEG biofeedback results for a 10 year old hyperactive boy who failed fourth grade in a class for the perceptually impaired. *Biofeedback and Self-Regulation, 18,* 33-44.

Tansey, M. A., & Bruner, R. L. (1983). EMG and EEG biofeedback training in the treatment of a 10-year-old hyperactive boy with a developmental reading disorder. *Biofeedback and Self-Regulation, 4,* 299-311.

Walker, S. (1975). Drugging the American child: we're too cavalier about hyperactivity. *Journal of Learning Disabilities, 8,* 21-25.

Wolraich, M. L., Lindgren, S., Stromquist, A., Milich, R., Davis, C., & Watson, D. (1990). Stimulant medication use by primary care physicians in the treatment of attention-deficit hyperactivity disorder. *Pediatrics, 86,* 95-101.

Diane C. Radvanski graduated Class Valedictorian and summa cum laude from Saint Peters College with a Bachelor of Science degree in psychology and Biology. She is a technician for Biofeedback Consultants Inc. And working in an elementary school. Her plans include graduate study in Health Psychology.

Sonia Wadhwani received her Bachelor of Science degree in psychology at Saint Peter's College. She is a Mental Health Worker at a therapeutic program for children and adolescents in Hoboken, New Jersey. Her goals include continued research and graduate study in clinical psychology.

Dennis P. Carmody, Ph.D., is a professor and former chairperson of the psychology department at Saint Peter's College. Earlier research focused on medical decision-making in radiology with consulting appointments at the University of Pennsylvania, the Long Island Jewish Medical Center, and the University of Medicine and Dentistry of New Jersey. Recent research involves interventions aimed at alterations in performance of children with developmental disabilities.