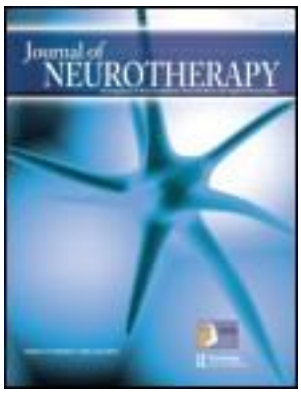

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Case Study: Improvements in IQ Score and Maintenance of Gains Following EEG Biofeedback with Mildly Developmentally Delayed Twins

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Case Study: Improvements in IQ Score and Maintenance of Gains Following EEG Biofeedback with Mildly Developmentally Delayed Twins

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ABSTRACT. This study reports on the improvements in IQ scores and maintenance of the gains following EEG biofeedback with identical twin girls with mild developmental delay and symptoms suggestive of Attention Deficit Hyperactivity Disorder (ADHD). Full Scale IQ scores increased 22 and 23 points after treatment and were maintained at three follow-up retests over a 52-month period. ADHD symptom checklists completed by their mother showed a similar pattern of improvement and maintenance of gains. The extent of improvement is supported by anecdotal reports of behavioral changes. The results are discussed in the context of other studies of EEG biofeedback also showing improved intelligence following EEG biofeedback.

KEYWORDS. Neurofeedback, EEG biofeedback, developmental delay, mild mental retardation, improving IQ, improving intelligence, treatment follow-up, maintenance of improvement, identical twins

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Advances in neuroscience bring hope that some day children with developmental delays can be systematically helped. EEG biofeedback is one intervention that holds promise in this regard. First discovered 30 years ago as a treatment for epilepsy (Sterman & Friar, 1972) EEG biofeedback, also called "neurotherapy" or "neurofeedback" has been applied to a range of disorders including Attention Deficit Hyperactivity Disorder (ADHD) and learning problems (Monastra, Monastra, & George, 2002; Nash, 2000; Othmer, Othmer, & Kaiser, 1999). Several studies have cited improvements in IQ scores as evidence that this treatment improves cognitive performance. Tansey (1991) reported improvements averaging 19.75 points on the WISC-R (Wechsler, 1974) Full Scale IQ score for 24 children with "neurological or perceptual impairments or attention deficit disorder." Using a random assignment wait list control design, Linden, Habib and Radojevic (1996) reported that the 18 participants who received EEG biofeedback showed statistically significant gain of 9 points on the K-Bit IQ Composite. Lubar, Swartwood Swartwood and O'Donnell (1995) reported gains averaging 9.7 points for 23 children; Othmer et al. (1999) reported an average gain of 23.5 points with a sample of 15 children and Thompson and Thompson (1998) reported 98 children gaining an average of 12 points. Fuchs, Birbaumer, Lutzenberger, Gruzelier and Kaiser (2003) reported an improvement of only 4 points in a study of 22 children. It is unclear what accounts for the variability in improvement. However, selection criteria and the training protocols were not homogeneous.

Only a few studies have addressed the issue of whether improvements are sustained. Tansey (1990) discussed the academic and behavioral changes achieved by his participants and included an anecdotal report suggesting continued progress. Tansey (1993) did report a 10-year follow-up with one participant though there were no specific data regarding intelligence test scores. Lubar (1995) published follow-up data on 51 participants for up to ten years after treatment. An independent professional evaluator, blind to the treatment, collected behavioral rating scale data via telephone interviews and found significant improvements in all areas. However, like the Tansey reports, there were no data regarding IQ scores.

Reports of increases in IQ scores for children with various attention, neurological and learning disorders is especially remarkable in that IQ scores are generally very stable and not particularly malleable (Brody, 1992). Cheng, Liu and Gong (1993) reported that across a 1.5 to 2 year interval, both learning disabled and normal children displayed stable Verbal, Performance, and Full Scale IQ scores on a Chinese version of the WISC-R. Streissguth, Randels and Smith (1991) reported that IQ

scores of patients with fetal alcohol syndrome or possible fetal alcohol effects remained stable over the average test/retest interval of eight years. Both Haddad, Juliano and Vaughan (1994) and Kaye and Baron (1987) reported that with learning disabled children WISC Verbal IQ scores tended to decrease while Performance IQ scores increased over a three-year period. Finally, Spitz (1986) reviewed the history of attempts to raise IQ in developmentally delayed and/or culturally disadvantaged children. Efforts included early intervention and compensatory education programs such as Head Start, behavior modification, medical and dietary interventions, and various sensory and motor therapies. He concluded that none have shown any significant effect in raising intelligence scores.

METHOD

Subjects

The participants were identical twin girls, eight years and five months old. Problems for both included being distractible, hyperactive and impulsive, with poor social skills, language and articulation problems, anxiety, obsessiveness, sleep problems and difficulty getting up in the morning. While their presenting problems were similar, Brenda's symptoms were slightly milder than Carol's (the names have been changed).

The girls were born two and a half weeks early without complications. Both girls were described as difficult infants who were delayed in walking and talking. When they were four their parents divorced. While they had observed conflict between their parents prior to the divorce, there is no indication that they experienced any particular psychological trauma. Their mother subsequently married their current stepfather. They were reported to relate well to him, something that was observed on occasions when he accompanied them to treatment. The girls attended second grade and were on Individualized Education Plans to help them in all academic areas and with speech and language. Throughout treatment and the follow-up period there were no changes in the family's living situation. At no time, either prior to or during the treatment was either girl medicated.

Measures

Intelligence test. Prior to treatment the Wechsler Intelligence Scale for Children-Third Revision (WISC-III; Wechsler, 1991) was independently administered. Brenda's Full Scale IQ was 71, her sister Carol's was

59. Interestingly, the girls had very similar WISC profiles with below average scores on every subscale except for the Digit Span test where both scored in the high average range (13 and 12, respectively).

Testing was repeated four months after the conclusion of treatment (seven months after the initial test). The retest was delayed to increase the test/retest interval and reduce the possibility of a practice effect. It was then repeated 20 months post termination and again 42 months and 52 months post termination. The pre- and post-treatment testing was done by the same individual who conducted the neurotherapy session. The initial follow-up testing was done by the author. The final two follow-up tests were administered by a third individual. All test administrators had appropriate training and qualifications to administer the tests.

ADHD symptom checklists. The girls' mother completed a checklist based on the DSM-III-R (American Psychiatric Association, 1987). Each symptom is rated on a four-point scale from 0 (not at all) to 3 (very much). For a few of the ratings, the mark was placed between two numbers. In those cases the rating was scored as between the number (i.e., 2.5). Ratings were averaged separately for distractibility, hyperactivity and impulsivity.

Treatment Procedures

Each girl received 40 sessions of neurotherapy. Treatment was terminated at that point because the parents were pleased with the results and because of time and expense considerations. Four years later, the parents indicated that while the prior gains had maintained and possibly extended, they were curious if further treatment would lead to further benefit. An additional 20 sessions of training were provided. A final round of assessments was done six months later.

EEG biofeedback was done with equipment from Neurocybernetics, a division of EEG Spectrum International (Canoga Park, California). The equipment uses two linked computers, one for the therapist to monitor the EEG and the other to provide feedback to the participant. Treatment protocols, including selection of the treatment site (Cz with reference to linked ears and ground attached to one ear) and the specific EEG bands for reward and inhibit fell generally within standard practice at the time (Sterman & Friar, 1972). Standard inhibit bands of 4-7Hz and of 22-30Hz were used to detect transient elevations in low-frequency and high-frequency EEG amplitudes, respectively. Standard reward bands of 15-18 Hz and 12-15 Hz were used for reinforcement of the sensorimotor rhythm in the classic Sterman/Lubar protocol (Lubar, 1995). The deployment of

either the 15-18 Hz or the 12-15 Hz reward bands was based on in-session and session-to-session symptomatic response of the participants. Based on recommendations of EEG Spectrum as practiced at the time of the study (Othmer & Othmer, 1992), the 15-18 Hz reward was intended to increase alertness while the 12-15 Hz reward was intended to improve calming.

Signal acquisition was with an analog amplifier with a gain of 10,000 and analog bandwidth of 0.5-30 Hz, with 12-bit digitization at 160 Hz. Signal detection was by means of digital filtering using Infinite Impulse Response (IIR) filters of two poles. Full-wave rectification was followed by smoothing using a 0.5-sec risetime, resulting in an overall group delay through the signal processing chain of less than 150 milliseconds. The reward and inhibit signals were then mapped into the speed and brightness of a PacMan-like object moving through a succession of mazes (to retain visual interest).

When either inhibit threshold was exceeded, the PacMan-like object stopped and went dark. Ordinarily, its speed and brightness would track the amplitude in the reward band in a manner that reflected the full dynamics of the signal in the reward band. An auditory beep was presented at fixed intervals of 0.5 seconds as long as both the inhibit threshold and the reward threshold criteria were met. The training thresholds were set in such a way that the reward criterion was met nominally 60% of the time, and the inhibit thresholds were exceeded no more than nominally 20% of the time.

Under such conditions the subjective experience of the training was such that the participant was motivated to "keep the beeps going," a sufficiently simple reward that it can engage even children who may be cognitively impaired or relatively unmotivated. The cessation of the beeps then yields an alerting response. The visual signal offers cues that allowed the brain to refine its responses to the reinforcement.

Signal integrity was assured by initial inspection and continuous monitoring of the EEG throughout the training session. This approach resolves an issue that often arises in clinical utilization of neurofeedback with young children who may be hyperactive, namely that the mere measurement of impedance prior to the initiation of training does not really resolve the issue of signal integrity throughout the session. On the other hand, continuous impedance measurements throughout the process compromise common-mode rejection unnecessarily and are therefore ruled out.[1] EEG aggregate measures were occasionally recorded but not in a systematic manner so as to allow changes in the EEG with treatment to be assessed.

Training was done two or three times weekly with sessions lasting 30 minutes. A technician was present during the session to adjust the thresholds and give encouragement for staying with the task. No specific instructions were given as to how to make PacMan move other than to suggest that the child pay attention to the screen. Over the course of therapy, whichever parent brought the children to the session was queried as to their progress. No other therapy was provided.

After 30 sessions both girls were becoming more anxious, a presumed effect of training with a 15-18 Hz reward band. Consequently, for six of the last ten sessions the reward band was shifted to 12-15 Hz for a more calming response. Shifting back and forth between the 15-18 range and the 12-15 range appeared to manage anxiety while advancing gains in cognitive ability.

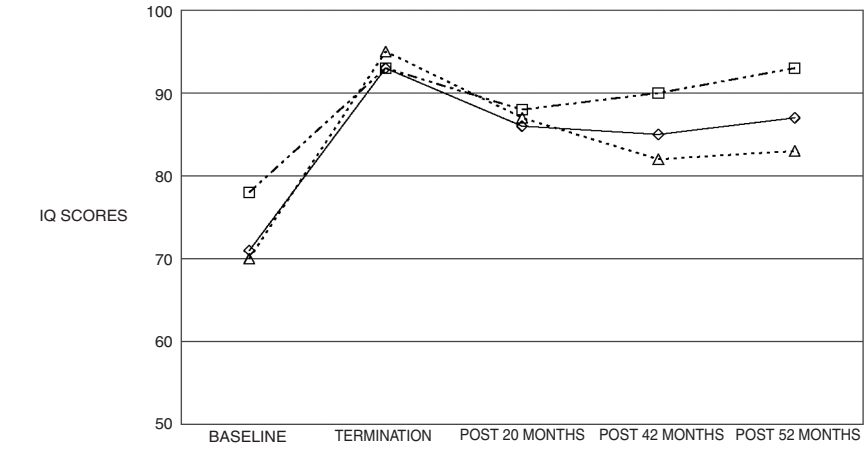
RESULTS

Intelligence Tests

Figure 1 shows the IQ scores for Brenda. Her Full Scale IQ increased from 71 before treatment to 93 after treatment, a 22-point gain. The 95% Confidence Interval for improved IQ scores would be a gain of 7 points or greater (Wechsler, 1991). All of her subsequent scores are outside that range indicating that the improvement did not simply reflect random changes in her scores. Similar analyses of changes in her Verbal and Performance IQ scores from her pre-treatment to after treatment and during the three follow-up tests also show that the changes all exceeded the 95% Confidence Interval. Her improvement dipped slightly at the initial follow-up but then stabilized. However, even with the dip, the scores continued to exceed the 95% confidence interval. Significantly, there was no trend suggesting further deterioration in the Full Scale IQ or in her Verbal IQ. However, the deterioration in her Performance IQ from termination to post 42 months and from termination to post 52 months was significant as being outside the 95% confidence interval. There was a non-significant improvement in both Verbal and Performance IQ from the post 42 months to post 52 months that suggests that the drop in Performance IQ had leveled off.

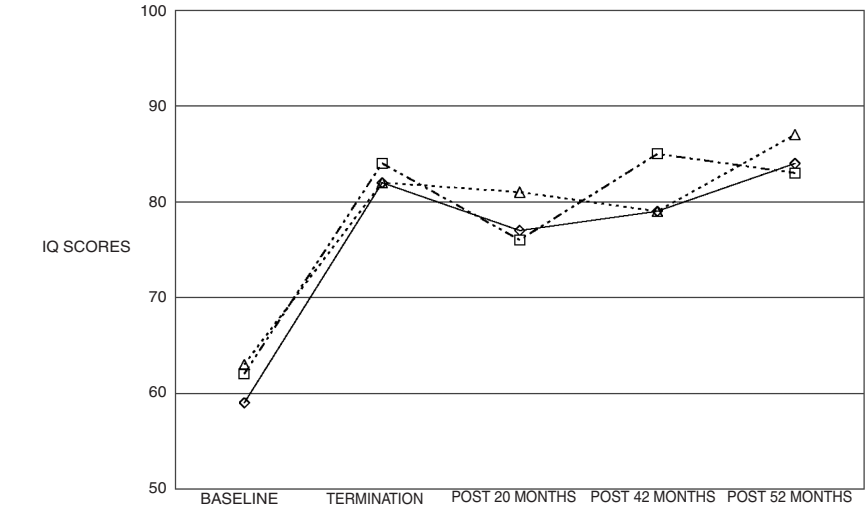
Carol's results are displayed in Figure 2. Her improvement of 23 points also exceeded the 95% Confidence Interval. Again, Full Scale, Verbal and Performance IQ scores dipped, though not to a statistically significant degree at the first follow-up and then made small steady gains

FIGURE 1. Brenda's WISC-III Scores



	BASELINE	TERMINATION	POST 20 MONTHS	POST 42 MONTHS	POST 52 MONTHS
FULL SCALE IQ	71	93	86	85	87
VERBAL IQ	78	93	88	90	93
PERFORMANCE IQ	70	95	87	82	83

FIGURE 2. Carol's WISC-III Scores



	BASELINE	TERMINATION	POST 20 MONTHS	POST 42 MONTHS	POST 52 MONTHS
FULL SCALE IQ	59	82	77	79	84
VERBAL IQ	62	84	76	85	83
PERFORMANCE IQ	63	82	81	79	87

at each follow-up testing. Like her sister, there were gains in Full Scale IQ from the post 42- to post 52-month periods during which the second round of training occurred. However, the gain in Performance IQ was significant for being outside the 95% confidence interval.

Symptom Checklists

Changes in Brenda's ADHD symptoms are reported in Figure 3. Over the follow-up period the pattern was of modest further improvements in distractibility. Carol's improvement in symptoms was similar to her sister's though the overall symptom count and symptom severity remained higher (see Figure 4).

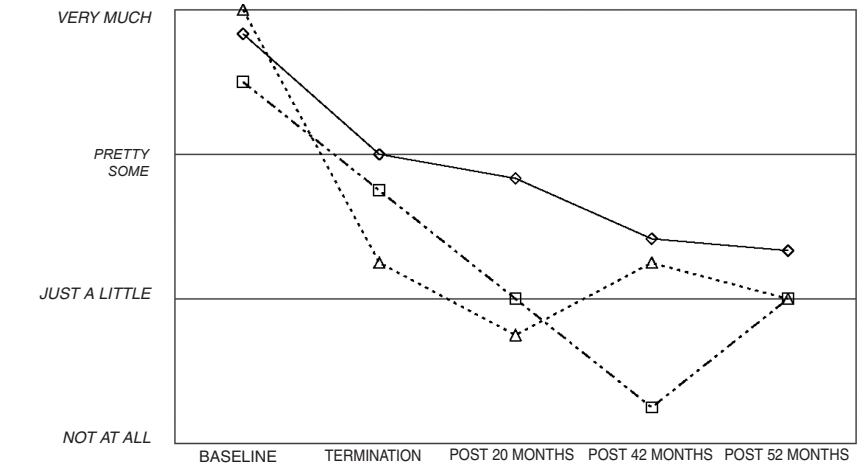
DISCUSSION

While based on treatment of only two participants, the results suggest that relatively dramatic improvements in IQ scores following EEG biofeedback could be achieved in relatively young children exhibiting mild mental impairment, and that these gains could be maintained over the long term. Of course, the results are only meaningful if one assumes that the pre-treatment IQ scores were valid. There are several reasons to accept this premise. First, the initial scores corresponded well to the girls' overall impaired functioning with language, social skills and physical coordination. Second, while anxious, the girls also liked to please, and having been made comfortable with the examiner, both girls willingly cooperated with the testing. Finally, on one of the scales, Digit Span, they both performed in the Above Average range. Poor cooperation or lack of understanding would have resulted in low scores on every subtest or outright failure to complete the test.

Was their improvement in IQ scores simply a function of improved attention? Interestingly, improvements on the four ACID subtests (Arithmetic, Coding, Information and Digit Span) cited as most reflective of attention problems (Wechsler, 1991) were smaller than those on the eight non-ACID subtests. Nor were the gains mainly on either the Verbal versus Performance Subscales or on the timed versus untimed subtests. Improvement was across the board though some subtests changed more than others.

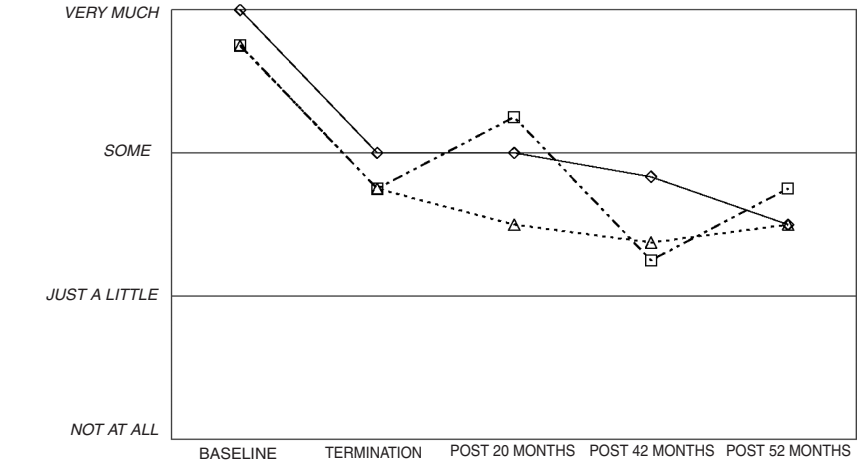
Nor do the gains in IQ scores seem to be simply a matter of being better at some narrow ability in test taking. Rather they appear to represent a qualitative jump in cognitive functioning including rapid gains in physical

FIGURE 3. Brenda's ADHD Ratings



	BASELINE	TERMINATION	POST 20 MONTHS	POST 42 MONTHS	POST 52 MONTHS
DISTRACTIBILITY	2.8	2.0	1.8	1.4	1.3
HYPERACTIVITY	2.5	1.8	1.0	0.3	1.0
IMPULSIVITY	3.0	1.3	0.8	1.3	1.0

FIGURE 4. Carol's ADHD Ratings



	BASELINE	TERMINATION	POST 20 MONTHS	POST 42 MONTHS	POST 52 MONTHS
DISTRACTIBILITY	3.0	2.0	2.0	1.8	1.5
HYPERACTIVITY	2.8	1.8	2.3	1.3	1.8
IMPULSIVITY	2.8	1.8	1.5	1.4	1.5

coordination, language and what might be described as a layperson's sense of intelligence. The following is from a letter their mother wrote at termination.

> Now that the biofeedback sessions are completed I can honestly say that it has made such a big difference in both girls. I don't know where to start! I went back through a journal that I had kept regularly throughout the biofeedback session. The first differences that we noticed, (after only 3 sessions) was a coordination improvement. Both girls–for lack of a better description–were clumsy. They couldn't ride bikes, [suspend themselves from] cross bars, climb, or slide down poles. And all of a sudden they are out crossing bars and after a few more sessions they were both riding bikes. It wasn't like before where everything they did was so "learned" or "taught." They just got on one day and in a few tries were off and running.
>
> Other things we noticed were the ability to carry on a two-way conversation. We had all of our family commenting on this – especially around 20 sessions. We had one friend who came to visit at Thanksgiving and said, "The girls have grown up, and they are talking to me instead of at me."
>
> The thing we are most pleased with is the progress they have made in school . . . they just seem smarter; they reason and think when they talk. They've gone from being extremely dependent to being average kids, the type that say, I'm going to go ride my bike, I'll check-in in awhile.

One intriguing question is why the second round of treatment was unable to produce further improvements in IQ scores. Is there a finite limit to improvement? Would the introduction of different neurotherapy protocols have achieved further benefit? Certainly this study suggests the need to replicate the study and the value of further research on neurotherapy with the mildly developmentally delayed. Even a modest favorable impact on level of intellectual functioning through neurofeedback portends significant societal benefits for the management of mild mental retardation and for the quality of life of the individuals concerned. Before this hope can be realized, however, there needs to be a more fundamental understanding of how neurofeedback can impinge on IQ through its reordering of cerebral control mechanisms in the bioelectrical domain.

NOTE

1. The approach employed in this study is based on the fact that the sole issue ultimately is signal integrity, and that integrity is directly dependent on the maintenance of common-mode rejection in the two arms of the differential circuit. In fact, analysis shows that channel balance in terms of contact impedance is really the crucial variable, not contact impedance itself (Ferree, Luu, Russell, & Tucker, 2001). Low contact impedance is one way of assuring that impedances do not differ too much, but if channel balance can be assured another way, the problem is also solved.

When common-mode rejection ratio is compromised, the signal reflects higher levels of 60-cycle pickup. This by itself is not a problem until it drives the detection circuit nonlinear and gives rise to aliasing within the signal bandwidth of interest. In the NeuroCybernetics system, signal sampling at 160 Hz aliases the third harmonic of the 60 Hz signal (180 Hz) into a twenty Hz signal that is readily observable on the clinician screen if it is an issue. Hence the clinician has a perpetual index to signal quality throughout the training process. The effectiveness of this strategy has caused routine impedance measurements to be abandoned.

REFERENCES

American Psychiatric Association. (1987). *Diagnostic and statistical manual of mental disorders* (3rd ed.). Washington, DC: Author.

Brody, N. (1992). *Intelligence* (2nd ed.). San Diego: Academic Press.

Cheng, Z., Liu, S., & Gong, Y. (1993). Stability of intellectual structure of learning disabled and normal children. *Psychological Science (China), 16* (3), 158-161.

Fuchs, T., Birbaumer, N., Lutzenberger, W., Gruzelier, J. H., & Kaiser, J. (2003). Neurofeedback treatment for attention deficit/hyperactivity disorder in children: A comparison with methylphenidate. *Applied Psychophysiology and Biofeedback, 28* (1), 1-12.

Haddad, F. A., Juliano, J. M., & Vaughan, D. (1994). Long-term stability of individual WISC-R IQs of learning disabled children. *Psychological Reports, 74* (1), 15-18.

Kaye, D. B., & Baron, M. B. (1987). Long-term stability of intelligence and achievement scores in specific-learning-disabilities samples. *Journal of Psychoeducational Assessment, 5* (3), 257-266.

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* (1), 35-49.

Lubar, J. F. (1995). Neurofeedback for the management of attention-deficit/hyperactivity disorders. In M. S. Schwartz (Ed.), *Biofeedback: A practitioner's guide* (pp. 493-522). New York: Guilford.

Lubar, J. F., Swartwood, M. O., Swartwood, J. N., & O'Donnell, P. H. (1995). Evaluation of the effectiveness of EEG neurofeedback training for ADHD in a clinical setting as measured by changes in TOVA scores, behavioral ratings, and WISC-R performance. *Biofeedback and Self Regulation, 20* (1), 83-99.

Monastra, V. J., Monastra, D. M., & George, S. (2002). The effects of stimulant therapy, EEG biofeedback, and parenting style on the primary symptoms of Attention-Deficit/Hyperactivity Disorder. *Applied Psychophysiology and Biofeedback, 27* (4), 231-249.

Nash, J. K. (2000). Treatment of attention deficit hyperactivity disorder with neurotherapy. *Clinical Electroencephalography, 31* (1), 30-37.

Othmer, S., & Othmer, S. F. (1992). EEG biofeedback training for hyperactivity, attention deficit disorder, specific learning disability, and other disorders (Unpublished report). Encino, CA.

Othmer, S., Othmer, S. F., & Kaiser, D. A. (1999). EEG biofeedback: Training for AD/HD and related disruptive behavior disorders. In D. Tessmer (Ed.), *Understanding, diagnosing, & treating AD/HD in children and adolescents* (pp. 235-297). New York: Aronson.

Spitz, H. H. (1986). *The raising of intelligence: A selected history of attempts to raise retarded intelligence.* Hillsdale, NJ: Lawrence Erlbaum Assoc.

Sterman, M. B., & Friar, L. (1972). Suppression of seizures in epileptic following sensorimotor EEG feedback training. *EEG Clinical Neurophysiology, 33,* 89-95.

Streissguth, A. P., Randels, S. P., & Smith, D. F. (1991). A test-retest study of intelligence in patients with fetal alcohol syndrome: Implications for care. *Journal of the American Academy of Child & Adolescent Psychiatry, 30* (4), 584-587.

Tansey, M. A. (1990). Righting the rhythms of reason: EEG biofeedback training as a therapeutic modality in a clinical office setting. *Medical Psychotherapy: An International Journal, 3,* 57-68.

Tansey, M. A. (1991). Wechsler (WISC-R) changes following treatment of learning disabilities via EEG biofeedback training in a private practice setting. *Australian Journal of Psychology, 43,* 147-153.

Tansey, M. A. (1993). Ten-year stability of EEG biofeedback results for a hyperactive boy who failed fourth grade perceptually impaired class. *Biofeedback Self Regulation, 18* (1), 33-44.

Thompson, L., & Thompson, M. (1998). Neurofeedback combined with training in metacognitive strategies: Effectiveness in students with ADD. *Applied Psychophysiology and Biofeedback, 23* (4), 243-263.

Wechsler, D. (1974). Manual for the Wechsler Intelligence Scale for Children-Revised. New York: Psychological Corporation.

Wechsler, D. (1991). WISC-III: Wechsler Intelligence Scale for Children-Third Edition. San Antonio: The Psychological Corporation.

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