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SPECIAL ISSUE

Training for Success in a Child with ADHD

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This article presents a case study to illustrate how children with attention-deficit/hyperactivity disorder (ADHD) can be assessed and successfully trained using neurofeedback. There is established efficacy for using neurofeedback to treat ADHD (Arns, De Ridder, Strehl, Breteler, & Coenen, 2009; Gani, Birbaumer, & Strehl, 2009; Gevensleben et al., 2009). Indeed, the American Academy of Pediatrics gave biofeedback Level 1 efficacy in its 2012 review (American Academy of Pediatrics, 2012), the same level of efficacy as is given to medications. The other condition that has sufficient randomized controlled studies to establish efficacy for electroencephalogram biofeedback is epilepsy (Tan et al., 2009). This case is presented to share techniques that will help clinicians conduct neurofeedback appropriately so that good results are obtained. The future of our field depends on every practitioner doing a quality job with excellent outcomes.

Case Study: N.E.

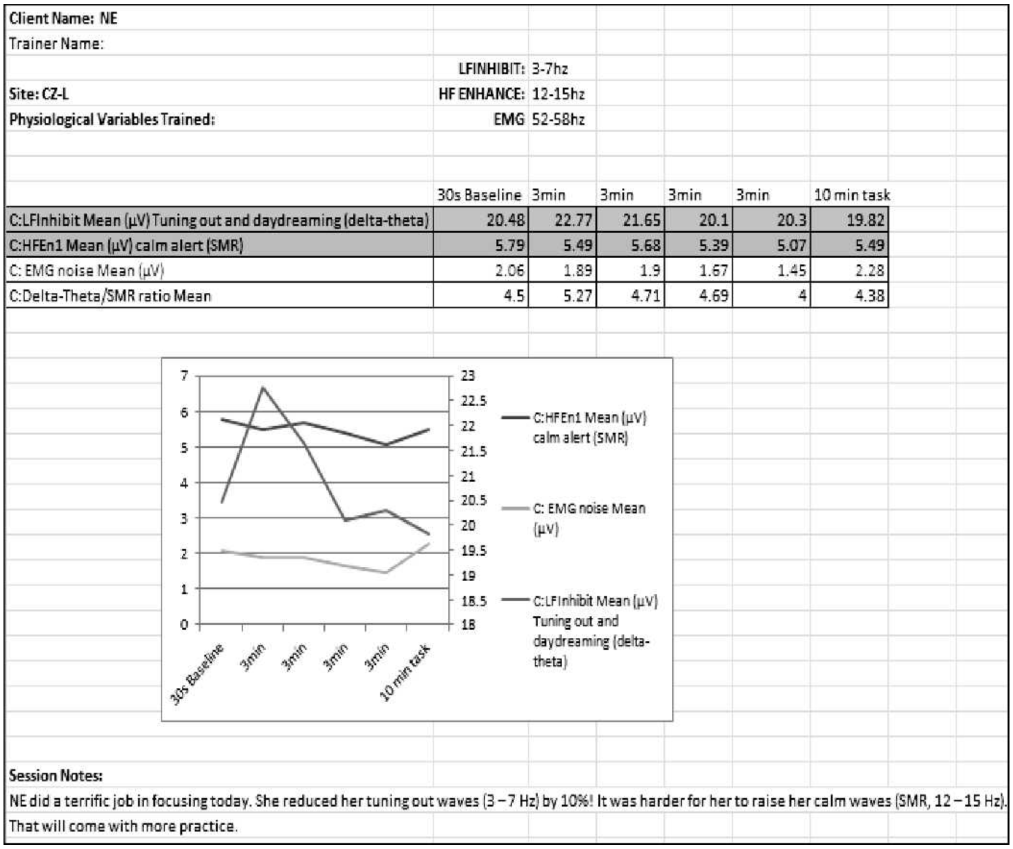
The first case is a 10-year-old girl, initials N.E., who met the *Diagnostic and Statistical Manual of Mental Disorders*, fourth edition (*DSM-IV*; American Psychiatric Association, 1994), criteria for a diagnosis of attention-deficit/hyperactivity disorder (ADHD), combined type. She completed initial training between July and November 2008, the first part of her fifth-grade year. Her parents, a lawyer and a government employee, had adopted her from an orphanage in Central America shortly before her third birthday, and she learned English when she came to Canada. Her primary symptoms included difficulty concentrating on her schoolwork, distractibility, and difficulty finishing tasks. She could complete assignments if a parent or teacher was with her, encouraging each small step. She had attended a private school and additionally received tutoring since the beginning of third grade.

A psychoeducational assessment done in 2006 had identified ADHD, but the parents did not want to use medication to control her symptoms. On intellectual assessment, there were strengths in verbal skills and poor spatial reasoning skills, a pattern sometimes termed a *nonverbal learning disorder* (NLD). Like most students with NLD, she was a bit socially naïve and had particular problems with organizational skills and math concepts. Among her strengths were being musical, enjoying active sports (such as soccer), and being a good swimmer.

Her personal goal for neurofeedback (NFB) training was to improve in math. Her parents stated that they primarily wanted their daughter to grow into a happy and fulfilled individual. Being able to maintain attention to tasks that others (such as teachers) felt were important, working neatly, and working with more persistence were also specific goals mentioned. Improved self-esteem was also a hoped-for outcome. Note that goals are always discussed during the initial interview to make sure they are realistic and attainable. They also become part of the written record (in the initial assessment report) that parents receive after an assessment.

Methods

A half-day assessment that included interviews, questionnaires, two computerized continuous performance tests (Test of Variables of Attention® [TOVA] and Integrated Visual Auditory® [IVA]), a draw-a-person test, and a single-channel electroencephalogram (EEG) assessment confirmed the ADHD diagnosis and indicated she would benefit from NFB training, because she showed a classic



Client Name: NE
Trainer Name:
LFINHIBIT: 3-7hz
Site: CZ-L HF ENHANCE: 12-15hz
Physiological Variables Trained: EMG 52-58hz

	30s Baseline	3min	3min	3min	3min	10 min task
C:LFInhibit Mean (µV) Tuning out and daydreaming (delta-theta)	20.48	22.77	21.65	20.1	20.3	19.82
C:HFEn1 Mean (µV) calm alert (SMR)	5.79	5.49	5.68	5.39	5.07	5.49
C: EMG noise Mean (µV)	2.06	1.89	1.9	1.67	1.45	2.28
C:Delta-Theta/SMR ratio Mean	4.5	5.27	4.71	4.69	4	4.38

Session Notes:
NE did a terrific job in focusing today. She reduced her tuning out waves (3 – 7 Hz) by 10%! It was harder for her to raise her calm waves (SMR, 12 – 15 Hz). That will come with more practice.

Figure 1. Sample Excel (Microsoft, Redmond, WA) spreadsheet showing a single channel neurofeedback training session for N.E.

pattern of excess slow-wave activity. She additionally showed a good response to the brief practice training session done at the end of the assessment. That demonstration session is important so that the student and the parents have a concrete idea of what the training will entail, which is important for decision-making purposes when they have to commit to doing 40 sessions of twice-a-week training. They can also see the learning curve that is generated (baseline followed by four 2-minute periods of feedback), so they know that progress will be measured and carefully tracked each session.

The goal of her NFB training sessions was for N.E. to become able to maintain a calm, relaxed, alert, and focused mental state. Eventually she had to maintain her focus while doing short (5- to 7-minute long) cognitive tasks using a metacognitive strategy that her trainer had taught her while she listened and maintained her focus. The basic analogy is that you are exercising the brain, so just as you do "reps" for various exercises when doing physical training, you do a series of short segments of NFB using different feedback screens with a brief rest in between while you review the statistics for that segment and give praise and tokens as appropriate.

Using a token system with children who have ADHD is hugely important for motivation, and it also ensures lots of positive interaction between trainer and student each session. Inherent in awarding tokens for success, whether it be for reducing theta or sitting still during a 2- to 3-minute segment, is an increase in feelings of self-efficacy. Self-esteem is built on solid achievements, and these within-training achievements are reviewed with the child and the parent at the end of each session. (Example: "N.E. did a terrific job in focusing today. She reduced her tuning-out waves (3–7 Hz) by 10% (Figure 1)! It was harder for her to raise her calm waves (sensorimotor rhythm [SMR], 12–15 Hz). That will come with more practice." Note the use of praise for a measurable achievement and setting of a positive expectation for future success.)

Training sessions for virtually all children at the ADD Centre combine some form of peripheral biofeedback (BFB) with NFB, but this child was not anxious and her parents wanted the sessions to focus on her attention span and use of cognitive strategies, so there was just a bit of "belly breathing" taught. Currently, heart rate variability training (HRV) is usually done. Skin temperature BFB, electrodermal monitoring, and surface electromyographic BFB

(SEMG) are also paired with NFB, with the feedback modality depending on the assessment findings regarding these variables. With adolescents and adults, a stress assessment is carried out (Thompson & Thompson, 2007). The main focus of coaching N.E. was to teach metacognitive (learning) strategies to improve spatial reasoning, math skills, time awareness/time management, and organizational skills. Handwriting was also practiced, because her messy writing was a problem.

Over a period of 4 months (July 2008 to November 2008), this client completed 33 sessions of NFB training combined with metacognitive strategies. Then, progress testing was done, and she graduated from twice-a-week to once-a-week training, finishing her training after 60 sessions. Her NFB training parameters were based on her initial single-channel EEG assessment at the central location (CZ). Note that a 19-channel quantitative EEG, with evoked potentials and HRV measurements added, is used in more complex cases, such as people who have suffered a concussion, but these tests are not considered necessary for children who present with only ADHD and with no history of head injury. These more complex assessments are now carried out using the Brain Interface Assessment and Treatment instrument from Evoke Neuroscience®.

Single-channel EEG ratios were collected by the second author (L.T.) using the methods developed by Lubar and colleagues (Lubar, 1991; Monastra et al., 1999). The instrument used in the assessment in 2008 was the Autogen A620® from Stoelting Autogenics. Currently, the Biograph Infiniti® from Thought Technology is used, but any instrument is fine as long as (a) it measures impedance before data collection is conducted, (b) it has an assessment screen that shows raw EEG while data are collected, (c) artifacts can be removed from the raw EEG, and (d) it generates an EEG profile in single-Hz steps, along with the corresponding statistics for each frequency and across selected frequency bands, such as 4–8 Hz or 12–15 Hz. The relevant assessment ratios used for this client were a ratio comparing theta to beta (4–8 Hz/16–20 Hz) and slow-wave activity to sensorimotor rhythm (3–7 Hz/12–15 Hz) with the ratio in microvolts, and the theta/beta power ratio ($[4–8\ \text{Hz}]^2/[13–21\ \text{Hz}]^2$) measured in picowatts. The initial power ratio values at Cz were consistent with the diagnosis of ADHD based on the Monastra et al. (1999) normative values. N.E.'s power ratio of 7.44 was well above the cutoff score of 5, which has 98% specificity for identifying ADHD in children.

The instrument used for training was the Biograph Infiniti from Thought Technology, and the screens were from the Thompson *Setting up for Clinical Success*® suite (M. Thompson & L. Thompson, 2001, available through www.BFE.org). This equipment has the capacity to simultaneously monitor and give feedback for EEG, SEMG, and peripheral BFB, and with most clients, some combination of these is used during training sessions. This child's NFB training consisted of 50-minute sessions that combined NFB with coaching in metacognitive strategies. (Sessions are booked on the hour, and 10 minutes is allocated to putting on electrodes initially and clean up and reviewing results at the end of the session, so 50 minutes is the typical time using the brain-computer interface training.)

The trainers at the ADD Centre come from a variety of educational backgrounds, such as psychology, teaching, medicine, nursing, occupational therapy, speech and language therapy, and social work. They all receive rigorous training regarding how to conduct NFB sessions. Although she had a primary trainer, N.E. worked with a number of different trainers and in different training rooms over the course of her sessions. Although it is vital to have good rapport between a client and a trainer in each session, using different rooms and trainers helps ensure that the training effects are dependent on the NFB and the learning strategies taught and not mainly on the relationship with a particular trainer. It also encourages generalization of the learning to other settings.

NFB is a form of BFB in which the client trains to control certain aspects of brain wave activity. NFB training settings are individualized based on assessment findings. This client was trained to decrease the amplitude and variability of her dominant slow-wave cortical activity (3–7 Hz/delta-theta). While reducing excess slow-wave activity, she was encouraged to increase SMR to 12–15 Hz activity. (The fast-wave frequency range is often changed to 15 to 18 Hz when the client is engaged in cognitive tasks, especially if no hyperactivity is present.) The electrode placement was at Cz, referenced to the left ear lobe.

Note that placement of the electrode and choice of reference site will depend on the assessment findings and the symptom picture plus what we know about neuroanatomy and neurophysiology, the decision-making triangle emphasized in *The Neurofeedback Book* (Thompson & Thompson, 2003). It is most frequently placed at Cz in young children. If the client is very impulsive and hyperactive, C4 is also assessed and used, depending on comparative findings with CZ. C3 and C4 placements offer a purer picture of SMR, whereas CZ reflects SMR in addition to other brain activity from the frontal lobes and from the anterior cingulate cortex that lies below it (Thompson, Thompson, Thompson, & Hagedorn, 2011).

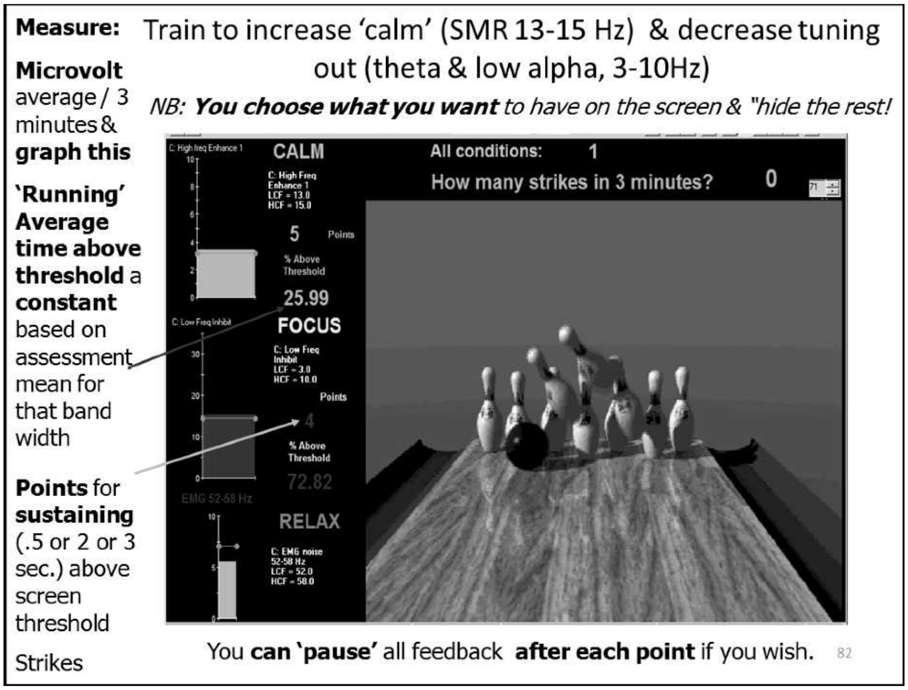


Figure 2. Example of a training screen made with Thought Technology Ltd. BioGraph Infiniti software (Thought Technology Ltd. Montreal West, Quebec, Canada).

The frequency range 52–58 Hz was used as an indicator of the effect of muscle tension (EMG) on the EEG, and if too high (>4 μV), activity in this range would inhibit feedback displays on all training screens. Most clients learn to keep it below 2 μV. The reason for the EMG inhibit bar graph on training screens is that the feedback received by the client should be due to their increasing true SMR (or 15–18 Hz beta activity, or other enhance frequency range as determined by assessment) rather than being due to increased muscle tension. Because muscle tension is higher voltage, it can artificially increase all the lower-frequency ranges and might cause the client to "learn" to increase muscle tension rather than true SMR amplitude.

Rewards were given by way of visual and auditory feedback from the computer, points accumulating on the monitor screen, and praise and a token reward system administrated by the trainer. Tokens awarded for effort and good performance were tracked in a bank account and could be exchanged for items from the ADD Centre store. Prizes range from small toys, books, model cars, stuffed animals, balls, board games, collector cards, and action figures to gift certificates for local bookshops, music stores, and movie theaters.

Points appeared on the screen for each 0.5 (initially) to 2 seconds (later in training) of appropriate activity, that is, when 3–7 Hz was sustained below threshold at the same time as 12–15 Hz was sustained above threshold and the muscle inhibit range of 52–58 remained low (Figure 2). Thought Technology equipment also provides information on the percentage of time above threshold (a constant numerical value) for each designated frequency range. The constant is entered into the client's database according to the mean value obtained during the assessment for each relevant frequency band after artifacting is done. This threshold constant is independent of where the trainer sets a threshold on bar graphs on the display screen, which is varied according to the client's success each day, so it allows for comparison across time and is not affected by the trainer's changing the threshold line on the screen when shaping the client's responses.

Shaping, in terms of operant conditioning techniques, refers to rewarding successive approximations toward a behavioral goal. You make the criteria gradually more difficult as the client experiences success. For example, the trainer could make the threshold easier for the client on a day she was tired so she would not be discouraged but then gradually make it more difficult as she achieved success. A child is told that he or she will get special extra tokens for succeeding when the threshold is made more difficult. The trainer is constantly observing and working with the client. A trainer should be tired at the end of a session! The thresholds, both the constant value and those that are changed "on the fly" during sessions, can be set according to the need of the particular client/student to emphasize increasing fast-wave activity (12–15 Hz in this case, but it will vary across clients), decreasing slow-wave activity in a particular range (3–7 Hz for N.E.), or decreasing high-frequency beta (greater than 20 Hz) when this correlates with inattention to assigned tasks (Thompson & Thompson, 2006). Feedback is both auditory and visual. The client receives primarily auditory feedback when working on learning (metacognitive) strategies; for example, while doing a reading task. The visual feedback consists of gamelike displays or scenes and can be changed according to a client's preferences on the Biograph Infiniti. Music/auditory feedback can also be customized for a client. As clients get proficient at these games, they can be challenged to produce good scores without feedback for 3 minutes while data are still being collected. These so-called transfer trials indicate whether the student is capable of turning on the desired mental state without external reinforcement, which supports transfer of the learning to home and school settings.

N.E. gradually learned to reduce her slow-wave activity (3–7 Hz) and increase her fast-wave activity in the SMR range (12–15 Hz) while inhibiting a range that reflects EMG muscle tension (52–58 Hz). She practiced quickly attaining a calm and alert state as soon as she sat down at each session. After doing a baseline recording each session, she did a number of reps, attempting to beat her own scores for two to four 3-minute segments. Then she would receive coaching in metacognitive strategies related to her school success while doing the NFB. She would then apply the strategy to a task, so-called on-task training. She would finish by doing just feedback again, without a task. She would earn 10 to 12 tokens each session in conjunction with improving her scores, sitting well, mastery of strategies, or external achievements, such as bringing in a good test result from school.

Note Regarding Metacognitive Strategies

Metacognition refers to thinking skills that go beyond basic perception, learning, and memory. It is the executive function that consciously monitors our learning and planning. Metacognitive strategies increase awareness of thinking processes (Cheng, 1993; Palincsar & Brown, 1987). As previously noted, the learning strategies are taught and practiced for approximately one third of each session while the client is receiving auditory feedback. These strategies help clients "think about thinking" and reflect on what they know about how they know and remember things. The strategies taught are different according to the individual client's needs. The following are among the most common strategies taught at the ADD Centre: active reading strategies, listening skills, organizational skills, reading comprehension, tricks for the timetables, solving word problems in math, organizing study time, creating mnemonic devices, other memory strategies, preparing study notes, and writing paragraphs/essays (Sears & Thompson, 1998; Thompson & Thompson, 1998; Thompson & Thompson, 2003). Essentially, clients become active learners. This is necessary for clients with symptoms of ADHD as they are not naturally reflective about the learning process and tend to become easily bored. Examples of metacognitive strategies are found in *The A.D.D. Book* (Sears & Thompson, 1998) and *The Neurofeedback Book* (Thompson & Thompson, 2003). In our case example, strategies emphasized spatial reasoning, organizational skills, and math problem solving.

Results

This client made significant gains on objective testing measures after 33 sessions of training. Note that progress testing is usually done after 40 sessions are completed, but it was done earlier for N.E., as sometimes happens for logistical reasons, such as wanting to measure results before a break in training necessitated by a lengthy holiday.

TOVA scores showed significant improvement in three subtest areas. Her ADHD score improved from –5.08 to –1.70 (scores of –1.80 and lower are considered significant for inclusion in the ADHD group on the TOVA). TOVA subtest scores are standard scores with a mean of 100 and a standard deviation of 15. Higher scores indicate improvement in symptoms. Her Inattention score went from 79 pretest to 102 posttest. On the Impulsivity measure, she made an impressive gain of 49 points, from a pretest score of 40 to a posttest score of 89. Both of these represent significant improvement. She also made great gains on the Variability measure, from a pretest score of 61 to a posttest score of 97. Her Response Time score decreased by 3 points, from 85 to 82. Thus, she showed a slower and more careful response style.

The IVA results showed that her fine-motor hyperactivity index went from moderate to none. Hyperactivity is measured by extra, unnecessary mouse clicks. Before training, N.E. had 23 unnecessary clicks, and after training, she had just 3 extra clicks. Her IVA Full Scale Response Control Quotient went from 81 pretraining, which is below average, to 87 posttraining, which is within 1 standard deviation. Auditory and visual response control standard scores went from 97 and 67 pretraining to 88 and 89 posttraining, respectively. Overall, scores for impulsivity were within the normal range posttraining. Her Full Scale

Attention Quotient improved from 73 to 97. Auditory Attention and Visual Attention scores that contributed to this quotient increased from 83 and 71, respectively, at pretraining to 100 and 90 posttraining. She thus showed improvement on nearly all of the standard score measures. The small decrement in auditory response control was associated with improvement to mid-average on auditory attention, suggesting that she got a little more impulsive along with being more vigilant in her listening.

Although questionnaire data are more subjective, they do indicate whether parents are seeing improvements in everyday life. The ADD-Q is a questionnaire developed at the ADD Centre for children and published in *The A.D.D. Book* (Sears & Thompson, 1998). The *DSM* ratings come from the SNAP version of the *DSM-IV* questionnaire developed by James Swanson and his group at the University of California, Irvine, for assessment and monitoring of ADHD symptoms. Conners' refers to the Conners' short form (10-item) questionnaire, which is normed (*Conners' Global Index for Parents*) and provides T-score values. For the total population, a mid-average T-score is 50. Scores greater than 65 (1.5 standard deviation) are considered indicative of a significant problem. Parent ratings indicated significant gains on the Conners' Global Index. The T-score went from 74 at pretest to 65 at posttest. She thus moved from significant for ADHD traits to just borderline for a diagnosis. Her ADD-Q score (Sears & Thompson, 1998) went from 38 pretest to 26 posttest, and scores on the SNAP version of the *DSM-IV* checklist changed slightly from 22 pretest to 21 posttest. Lower scores on the ADD-Q and the *DSM-IV* criteria represent fewer and/or less severe symptoms.

With respect to single-channel EEG changes, the client's picowatt (power) ratio was 7.44 initially and 5.96 after her first 33 sessions. The pW ratio is calculated as (4 to 8 Hz)^2/(13 to 21 Hz)^2. Other ratios were as follows:

Pre: μv ratio (4–8/16–20): 4.20
μv ratio (3–7/12–15): 4.76
Post 33: μv ratio (4–8/16–20): 3.38
μv ratio (3–7/12–15): 4.39

As can be seen from the pre and post results of the single-channel EEG, critical ratios decreased in the first 33 sessions, although they still remained a bit high. The EEG changes were associated with a calmer and more focused mental state. Because the power ratio of 5.96 after 33 sessions was still in the range associated with a diagnosis of ADHD (5.0 is the 1.5 standard deviation cutoff score for ages 6–11 years), more training was indicated. Having seen the results obtained with 4 months of training, her parents were happy to have their daughter continue training. This was done on a once-a-week basis, and she completed a total of 60 sessions of training over the course of the next year, with a further decrease in the theta/beta ratio and further behavioral improvements.

Administration of the Wechsler Intelligence Scale for Children–Fourth Edition (WISC) was done after 60 sessions of training were completed, and although the Full Scale IQ did not change that much (it increased from the 47th to the 50th percentile rank), her Index scores were much more even than in 2006 and no longer indicative of NLD. Her Perceptual Reasoning score had increased impressively from the 7th to the 42nd percentile rank. This perhaps reflected her application of verbal mediation strategies she had learned during her training: She could now talk her way through tasks requiring spatial reasoning. Reduced impulsivity can also improve scores on the WISC, and she did show a slower and more careful style. Taking her time meant that Processing Speed scores declined from the 84th to the 42nd percentile rank. Verbal Concepts had a lower score (79th to 55th percentile rank), whereas Working Memory had improved from the 42nd to the 63rd percentile rank. Working memory is affected by attention, so it is one of the scores that usually improves with training.

Conclusions

As can be observed from this case study, assessment results guide training parameters, and then progress is tracked with learning curves for every session. The combination of NFB with learning strategies (teaching metacognition) is posited to help generalization of self-regulation skills to everyday life. The case chosen had a good outcome but was less dramatic than the majority of cases at the ADD Centre as reported in the L. Thompson and M. Thompson (1998) review of 111 cases. NFB is an effective intervention for individuals with ADHD when properly applied.

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