Development History of the Othmer Method:

1987 to 2016

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Introduction

During the last half-century mental dysfunctions have come to be understood in terms of neural network relations rather than in terms of specific deficits in neuromodulator systems. Deficits lie in the realm of brain dynamics and of functional connectivity. Both of these are subject to dynamic regulation and thus in principle subject to recovery by functional means. Over the same time frame, strategies of assisted self-regulation have matured on the basis of real-time information derived from the EEG or from glucose uptake in functional brain imaging. These testify to the presumptive recovery potential through the enhancement of self-regulatory capacity.

Two principal strategies have emerged. One is a prescriptive strategy based on the discernment and targeting of specific deficits that can be observed in the EEG; the other is a non-prescriptive strategy for the recovery of functional competence in more generality. The top-down prescriptive strategy lends itself readily to evaluation by the usual tools of academic research. Such is not the case with a non-prescriptive, open-ended, bottom-up strategy. And yet such an approach has great appeal, largely because it emulates how the brain acquired its self-regulatory capacities in the first place. It merely augments that process with physiologically relevant real-time information and salient cues.

The Othmer Method is a systematic, sequential, hierarchical approach to a non-prescriptive strategy for the recovery and enhancement of functional competence. This has been the objective of a substantial development effort over the last thirty years. The evolution of the method has depended on new initiatives in signal recovery and signal analysis, on progress in the theoretical understanding of cerebral functional organization, on clinical observation and research, and finally on empirical validation through a large practitioner network.

The following is a brief recapitulation of the publication milestones that helped to shape the development of the method and to document its clinical effectiveness.

Developmental Milestones of the Othmer Method

The development of the Othmer Method of neurofeedback began with the protocols first used with human subjects by the pioneering researchers M. Barry Sterman and Joel Lubar in the 1970s and 1980s. Both targeted the reduction of motoric excitability by means of reinforcement of low beta band EEG amplitudes on the sensorimotor strip. Sterman sought the amelioration of seizure susceptibility (Sterman, 2000; Sterman & Egner, 2006), whereas Lubar sought the remediation of hyperkinesis in children (Lubar & Lubar, 1984). The technique was operant conditioning, which allowed the use of simple feedback schemes that could be readily implemented with the analog instrumentation available at the time.

The very first innovation of the Othmer Method was to utilize the full dynamics of the reward band directly in feedback. This development was contingent on the computerization of the method, thus allowing video feedback, which was accomplished by 1987. The instrument was named the NeuroCybernetics. This simple change led to a distinct advantage over systems that utilized feedback based on frequency-domain analysis using the Fast Fourier Transform (FFT), which was the obvious alternative once the method was computerized. The feedback became more “real-time,” and hence more engaging to the brain. This innovation was gradually adopted broadly within the field and FFT-based feedback was largely abandoned over that same time frame of six to nine years.

Not fully appreciated at the time was the fact that the “added value” of utilizing the full dynamics in feedback represented a departure from the operant conditioning model. After all, the rich information stream was provided without bias---beyond a general favoring of large signal amplitudes that was implicit in the feedback. This conclusion became inescapable after the operant conditioning aspect of the training was later abandoned entirely with the entry into the infra-low frequency region. The development trajectory is elaborated in the following.

There was yet another departure from standard operant conditioning. The role of the discrete rewards in the Othmer Method was not the classical one of B.F. Skinner. In what was perhaps the very first instance of the individualization and optimization of the training procedure, the reward incidence was progressively moved upwards over the years to the point where it was always kept high, whereas in the Skinner model the rewards had to be sufficiently rare to be accorded special significance. At high reward incidence, the discrete rewards became rate-limited (at two per second) and thus acquired a kind of cadence. The trainee came to seek continuity in the regular flow of auditory ‘beeps.’ The rewards had become state-dependent instead of being explicitly event-related. The attended ‘event’ became the occasional dropout of the beeps rather than their occasional presence, the very opposite of what transpires in the Skinner model. The discrete rewards had undergone a role reversal. They were functioning more like an inhibit than a reward.

The second distinguishing feature of the Othmer Method was the exclusive reliance on bipolar montage. This was not a novelty at the time, however. Use of bipolar montage was customary in the EEG field in the early days. Indeed, the entire published clinical work by M. Barry Sterman, who initially established what he called sensorimotor rhythm (SMR) neurofeedback on the basis of an animal model, was based on the use of bipolar montage. The same held true for the early work of Joel Lubar. However, this approach was widely abandoned with the adoption of QEEG-based targeting in the early nineties. Once site-specific information became readily available with digital analysis of the EEG, it was also targeted explicitly in the training. Othmers adopted referential placement at that time as well, following the lead of Barry Sterman, but after a few years returned to the exclusive use of bipolar montage (~1997). This went against the grain of the then-reigning localization hypothesis, but it made for more impactful feedback. The brain could relate more effectively to the relationship between two sites than to the amplitude at a single site.

The third critical innovation was the discovery that the reward frequency needed to be individualized for each trainee (1998-2000). This improved the effectiveness of the training with every individual, significantly increased the success rate, and extended the reach to include a wider range of clinical syndromes (e.g., Dystonia, tremor, Parkinson's, autism, cerebral palsy, and what is now referred to as Developmental Trauma).

The optimization procedure then led to the further discovery that all conditions subsumed under the rubric of "brain instabilities" respond to the same inter-hemispheric placement, T3-T4. This category includes seizure disorder, panic, migraine, and Bipolar Disorder. Additionally, they all respond most favorably at the same target frequency, which is referred to as the Optimum Response Frequency (ORF). In rare cases, homotopic inter-hemispheric placements other than T3-T4 were required.

Optimization of the target frequency was most critical in the case of brain instabilities, so these became the tip of the spear in the subsequent exploration of the EEG frequency domain. Optimum response frequencies could be found anywhere within the conventional frequency range out to 40 Hz. In the 2001-2003 timeframe the range of ORFs was extended down to the lowest frequency band that was consistent with 3-Hz bandwidth, a center frequency of 1.5 Hz. Concurrently, other inter-hemispheric homotopic placements were added to augment T3-T4.

The next innovation was the discovery, in 2006, that the distribution of ORFs extends below the EEG range into the region of the Slow Cortical Potential (SCP). Reference here is to the tonic rather than the phasic SCP that is usually implied. The tonic SCP is a correlate of local cortical activation, and in bipolar montage yields the differential cortical activation between the two training sites.

Entry into the infra-low frequency region with what came to be known as Infra-Low Frequency (ILF) training led to the complete abandonment of the operant conditioning aspect of the training. The procedure could no longer be threshold-based except for the inhibit aspect of the protocol. Hence there was no longer any reward on offer. There were no reinforcers of any kind. This merely put the seal on what had already become an operational fact even in the EEG regime, namely that the operant conditioning aspect of the protocol had been playing a minor role throughout the entire development of the Othmer Method.

The final innovation emerged out of the experience with ILF training. It is the sequencing of the training priorities to align with the developmental hierarchy, which begins with right hemisphere-dominated regulatory functions and with the parietal hub of the Default Mode Network. This leads, then, to the sequential re-normalization of functional connectivity of the intrinsic connectivity networks. Early maturation of core regulatory function is the primary burden of the right hemisphere, which calls for right-hemisphere priority in the training.

The collective training process has the features of a scaffolding procedure in which the early training lays the foundation for the functional enhancement of higher functions that are only targeted explicitly later in the procedure. Collectively the training amounts to a recapitulation of the trainee's developmental sequence, with presumptive incremental functional re-normalization at every step.

The Philosophy Guiding the Research

The Othmer Method was established and validated on the principle of practice-based evidence. This was necessitated by the complete lack of interest among the national (U.S.) funding agencies in the investigation of these and related technologies. This has been the case since 1985, which just happens to be the year Othmers entered the field. Formal research for the purpose of demonstration to the broader scientific community was then always either conducted or evaluated by others with whom they collaborated, or it was performed by entirely independent parties that relied on their protocols, their instrumentation, or both.

That approach was mandated on the rationale that Othmers' own studies would necessarily lack the independence that one would like to see in validation studies. Since the Othmers' own research would always remain somewhat suspect in formal studies, they have always been dependent on others showing interest in researching their methods. Concurrently, data have been accumulated on all clinical outcomes over the years at the EEG Institute. For objective data, reliance has been placed on the continuous performance test since 1990.

It must be acknowledged that Othmers have always had very limited objectives in any research on their methods. The objective in formal studies was always to demonstrate outcomes rather than to prove efficacy. That was because efficacy was no longer in question. The basic issue of neurofeedback efficacy had been settled formally by Sterman and Lubar. That did not have to be proved all over again. The placebo ghost had already been quarantined with animal studies on cats and monkeys. It was left only to demonstrate the clinical effectiveness of the method in different applications and for various client populations.

With respect to that objective, clinical benefit needed to be obvious and unambiguous---and with the Othmer Method in particular that was usually the case. If clinical benefit had to be teased out with statistics in large-scale studies, then it would likely not be worth the effort. After all, neurofeedback is time-, labor- and resource-intensive. There would be no point in chasing small effects.

Given the optimization procedure, every client is his own control in an ongoing A/B design. Every forward step is contingent on progress with the prior step. The assumption of progress is therefore built in to the procedure: in its absence the process does not continue. On that basis, progress cannot also be a hypothesis subject to independent evaluation. The only group studies that make sense in this context are outcome studies, and such studies can be performed sequentially rather than in parallel.

Standard research designs are ruled out in any event. The ongoing contingency of training procedures rules out blinding of the therapist, and insistence on fixed protocols would represent a Procrustean bed to the Othmer Method. The parametric dependency of the clinical effects demonstrates in each case that the outcomes are not reducible to a placebo effect. For that reason, studies to rule out the placebo are obviated. It goes without saying that placebo effects are in play in this procedure, just as they are in general in health care. It is merely asserted that the outcomes are not explainable in those terms.

Published studies have documented the various milestones of progress in the development of the Othmer protocols. The key studies are introduced in the following section, followed by a listing of the relevant references in their approximate chronological order.

Research Milestones of the Othmer Method

Targeting ADHD and its comorbidities

The first formal study involved simple beta1 band (15-18 Hz) reinforcement training in application to ADHD and its associated comorbidities (1990-1). This study utilized bipolar montage at C3-T3. Pre-post analysis was performed by the Principal Investigator, Dr. Clifford Marks, who had no role in the training and no other connection to the Othmers' Institute. His sole compensation was what he could collect from insurance. Dr. Marks selected the tests that he thought would be appropriate: The Wechsler IQ test, the Benton Visual Retention Test, the Tapping Subtest of the Harris Tests of Lateral Dominance, and the Wide Range Achievement Test (reading, spelling, and arithmetic). The Wechsler IQ test was chosen because it is constructed to evaluate a broad variety of functional domains efficiently.

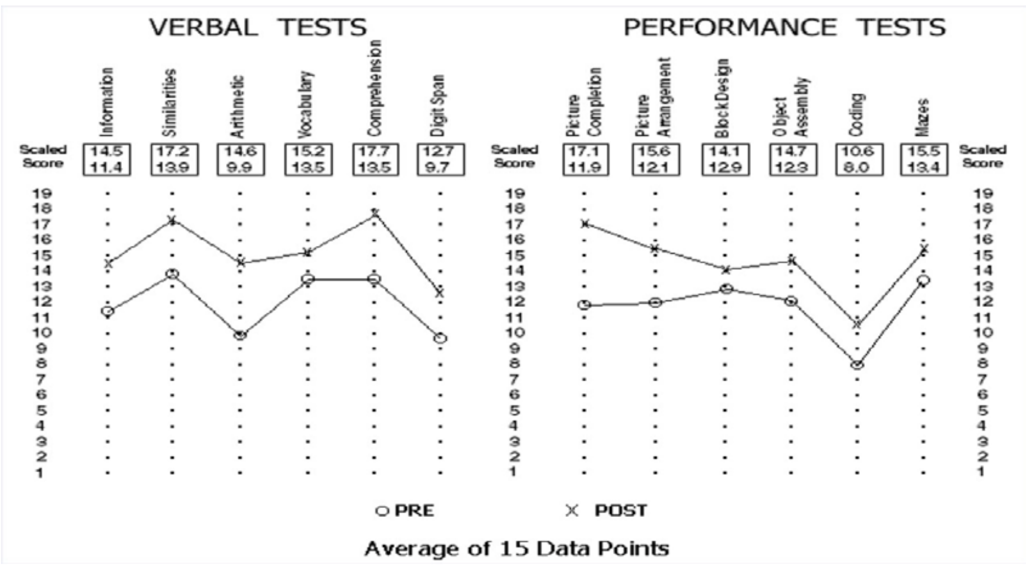

Figure 1. Wechsler IQ score (WISC-R) before and after neurofeedback training for a mixed cohort of ADHD and learning disabled children. The mean gain in IQ score was 23 points in Full Scale IQ.

The most salient finding was an average increase of 23 points in WISC-R IQ score, as shown in Figure 1. The individual improvements in IQ score are shown in Figure 2. All but two of the participants improved in IQ score beyond test-retest uncertainty. All those who initially tested below norms improved on the order of 30 points in IQ score. When subtest scores are surveyed, all participants improved significantly in at least some functional domains. There was considerable heterogeneity in the individual response curves; they did not necessarily resemble the average shown in Figure 1. Declines in subtest scores were, however, virtually absent, and in any event within the scope of test-retest uncertainty.

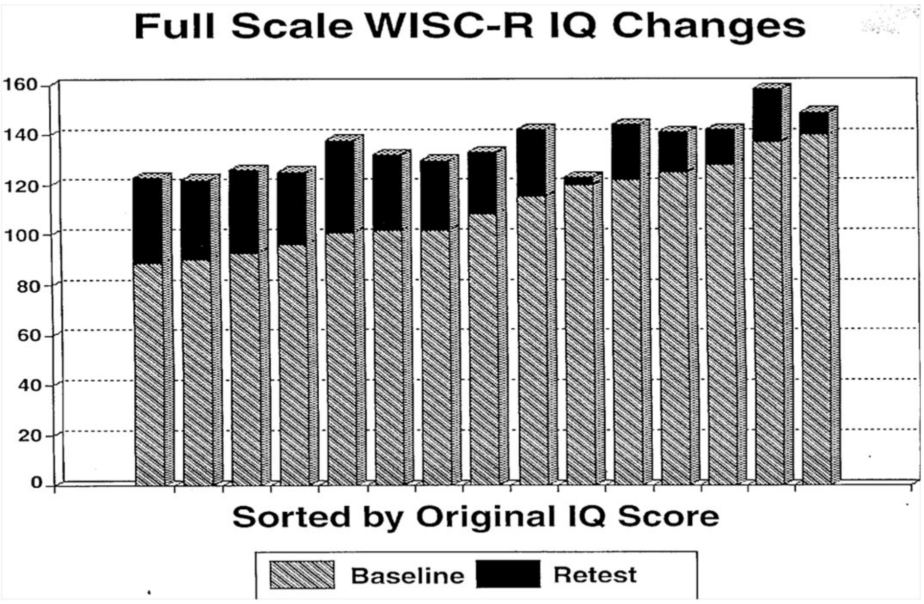

Figure 2. Individual changes in IQ score for study participants. All but two showed gains exceeding test-retest uncertainty. All those testing at or below 100 at the outset gained on the order of thirty points or more.

Results for the Benton Visual Retention Test are shown in Figure 3. Notably, six who initially scored between defective and average ended up testing in the superior range. Of the eleven who initially tested below average, eight ended up with average scores or above. On the tapping test the average improvement in score was 40%, with three children improving their performance by over 100%. Two of these three children changed from left- to right-hand dominance with the training. There was a dropout of mixed dominance as children either acquired or consolidated their native laterality.

The laterality reversals likely constitute the most incontrovertible evidence up to this point that core neurophysiological functional organization is being impacted with the training. Such changes cannot reasonably be assigned to a placebo, particularly since both reversals were accompanied by performance improvements of more than 100%. It appears that latent functional competence was unleashed with the restoration of native laterality. Reversals are most prominently associated with the birth process, as indexed by thumb-sucking preference before and after birth. Perhaps the neurofeedback training is reversing the functional impacts related to birth trauma.

Additionally, the training led to the systematic resolution of behavioral complaints, attentional deficits, sleep disregulation, and pain syndromes (head pain and stomach pain). One child radically improved his hand-writing. The most prominent outcome in terms of self-report was improved self-esteem. Dr. Marks was quite shocked when he undertook the re-testing: “These children are different.” Years later, some parents returned with or without their young adults to tell us that this training had been the turning point in their children’s lives.

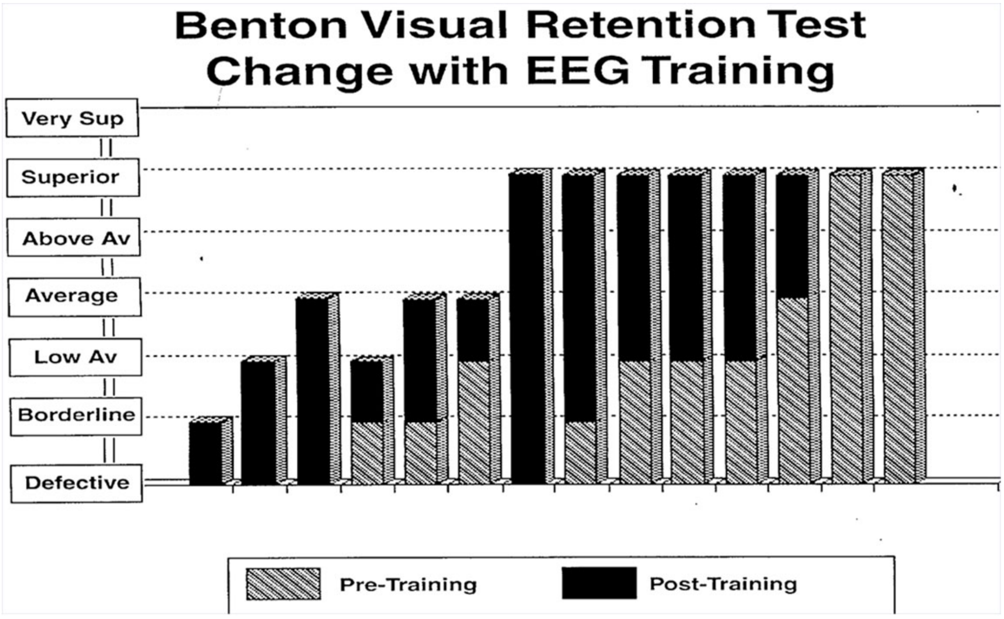

Figure 3. Individual changes in score for the Benton Visual Retention Test. The generally low initial test scores, with 11 of 14 testing below average, are in contrast to the IQ scores, where only four tested below average. Only 14 are shown because one pre-test was lost from the records.

This study also served the purposes of testing the hypothesis that beta1 band reinforcement was preferable to the SMR-band training (12-15 Hz) at Cz that had been employed by Michael Tansey in his finding of nominally 20-point gains in mean IQ in a cohort of 24 children with minor neurological impairments (Tansey, 1990). The results of both studies were very similar in their particulars with respect to the subtests of the WISC. The correlation between them, shown in Figure 4, augurs for the validity of both.

This work encountered the objection from critics that altering IQ was known to be quite impossible, and that the publication of this work would therefore bring neurofeedback into disrepute rather than providing a basis for its further recognition. Criticisms from academia were even harsher. Russell Barkley, for example, insisted that only a fully controlled design would be considered for publication, an illogical position because if IQ change is impossible then it couldn’t every well happen by placebo. The only way to break out of that intellectual cul-de-sac was with evidence that IQ scores could in fact be readily improved, the very evidence we had in quantity between Tansey and the present study. The difficulty was the usual one, the absence of a model in terms of which these results would make sense. It must be remembered that in 1991 the notion of brain plasticity was not yet generally accepted.

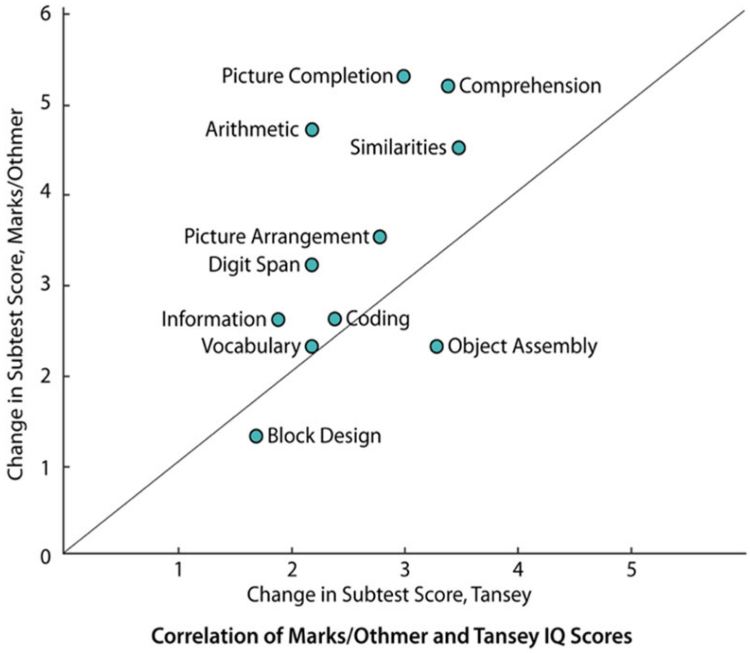

Figure 4. WISC-R subtest average gains for the present study plotted against the subtest average gains in the prior Tansey study. Correlation in the measures is indicated. The populations were not matched, so more specific comparisons are not warranted. (The Mazes subtest is not plotted because it was not characterized in the Tansey study.)

The study was finally published by the Biofeedback Society of California in 1992, but even here the matter was not without controversy. Further, it was unlikely to be seen by anyone outside of the field (Reference 1). In 1999, the results of this study were detailed in two book chapters, along with other corroborative data that had been gathered by that time (Ref. 2 and 3).

In 1993 a controlled study using Othmer protocols with ADHD as the target was undertaken by Drs. Aubrey Fine and Larry Goldman at California Polytechnic State University of Pomona. There were three groups: a neurofeedback training group; a cognitive skills training group; and a wait-list group that was given the opportunity to train later. Participants were solicited from various pediatricians, who referred their most challenging cases, where medication had not normalized the behavior. Some 85% of the participants were medicated, and 15% were on two or more medications. The neurofeedback consisted of 20 half-hour sessions, with the option of continuing for another 20 sessions. All of the training was done at an Othmer clinic. 71 children completed the study.

Since there could be no contact between the trainers and the referring physicians, there was no opportunity to co-ordinate re-titration of the medication as the neurofeedback took effect. This constituted a significant constraint on the study results, as well as a departure from actual clinical practice.

Initial results were presented in a poster at the Los Angeles APA annual meeting in 1994 (Ref. 4). This elicited a hostile and critical response from Russell Barkley. Having praised the study design effusively, he was in a position to assert firmly that neurofeedback had been discredited. Subsequently, the authors abandoned their intention to publish the results, quite possibly in consequence of that critique. It was implicit that they would be placing their professional reputations at risk to pursue their interest in neurofeedback. The outcomes for the training of the control group were never made available.

The results for the treatment group were actually dramatically favorable. With respect to the behavioral indices derived from parent ratings, significant gains were found for eight out of twenty-one categories:

Revised Conner's Questionnaire:
Scale B: Learning Problems ($p < 0.01$)
Scale D: Impulsive Hyperactivity ($p < 0.01$)
Scale F: Hyperactivity Index ($p < 0.01$)

On the Child Behavior Checklist:
Scale I: Schizoid or Anxious ($p < 0.01$)
Scale II: Depressed ($p < 0.01$)
Scale VI: Social Withdrawal ($p <0.01$)
Scale VII: Hyperactive ($p < 0.01$)

Home Situations Questionnaire:
Mean Severity ($p< 0.05$)

With respect to the cognitive skills tests, on the other hand, there were only two significant improvements for the neurofeedback group, out of a test battery of 30 items:

Wide Range Assessment of Memory and Learning (WRAML):
Number/Letter Memory ($p < 0.01$)
Stroop Test, Items completed ($p < 0.05$)

However, it should be noted that most of these latter tests were included to evaluate the cognitive skills training arm of the program. They are not standard criteria for evaluating remediation of ADHD, nor are they standard criteria for evaluating the effectiveness of stimulant medication. Moreover, the training cohort was not selected on the basis of initial deficits in these areas. And yet it was largely these results, or rather the lack thereof, that Barkley highlighted to dismiss neurofeedback as having any merit.

The next published study focusing on the ADHD spectrum was by Marabella Alhambra, MD, a neurologist. This study was published in the first issue of the Journal of Neurotherapy in 1995, and documented progress in training of 36 ADHD children with various comorbidities (Ref. 5). The study reflected the results after 20 training sessions, even though all the children continued on to 30 sessions. 31 of the 36 improved with the training, and 30 did so significantly. Of 31 showing deficits on the TOVA, 23 demonstrated significant improvement. 16 of the 24 who had been taking medication were able to discontinue it or to reduce the dosage. Comorbidities improved as well.

The next published study was in 2000 by Kaiser and Othmer, with the objective of assessing the results that were being obtained by practitioners who utilized the NeuroCybernetics instrumentation and the then-current Othmer protocols (Ref. 6). Some 32 private clinics were included in the survey, and the total sample size was over 800. The protocol utilized in this observational study was a combination of beta 1 band (15-18 Hz) reinforcement at C3 with SMR-band (12-15 Hz) reinforcement at C4, in a sequence and a ratio that were tailored to the needs of the trainee. This protocol was widely adopted within the growing field during the nineties and came to be known simply as “C3beta/C4SMR.“

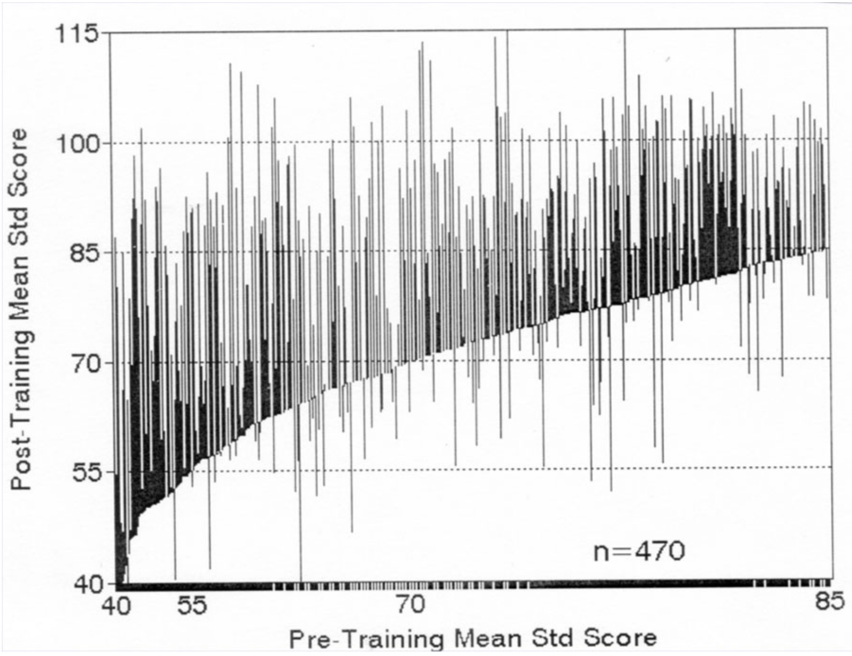

Figure 5. Changes in standard score for the impulsivity measure obtained with neurofeedback training. Shown are those cases where the pre-training score was less than 85 (16th percentile). Data are plotted rank-ordered in terms of starting value. The data are densely packed, so that the horizontal scale is nonlinear. All initial values of less than forty were arbitrarily assigned an initial value of forty. A score of 40 is four standard deviations below the mean.

Some 85% of the trainees benefited from the procedure to a clinically significant degree, as judged with a Continuous Performance Test (the T.O.V.A.). Pre-post comparisons are shown for the impulsivity measure in Figure 5. Only those scoring less than 85 in standard score at the outset are shown. The adverse outcomes shown in the Figure testify to the immature status of the field at the time, with only a single protocol and no adaptability. Nevertheless, the adverse outcomes yield useful testimony against the placebo model. This training procedure is not innocuous. Lumping negative and positive outcomes together, more than 90% showed change beyond test-retest uncertainty in the CPT data.

It should be noted that data for adults show a much lower incidence of adverse changes. There is also a systematic bias in the above data in that re-tests of school children often took place after school, whereas the test is normed for the morning hours. Parents could be induced to take their child out of school for the pretest, but not for the re-test. After all, they were not still in doubt that their child had been helped.

The Addiction Study

The next published study by Othmers involved the application of neurofeedback to the problem of addiction. The original motivation was to produce a replication of Eugene Peniston’s highly successful studies with Alpha-Theta training of Vietnam era veterans with a twenty-year history of PTSD-related alcoholism. The Peniston Protocol was slightly altered, however, to insert our "C3beta/C4SMR" protocol training in the place of Peniston's temperature biofeedback training. The intent was to normalize psychophysiological functioning, as indexed by TOVA scores, before starting the Alpha-Theta training. TOVA scores were normalized in an average of 13 training sessions. The program was also opened up to other drugs of choice: crack cocaine, methamphetamine, and heroin.

This study remains the largest controlled study ever done in neurofeedback up to the present date (2016). It involved some 121 participants at the residential treatment center that had responsibility for the program. The control condition was the standard Minnesota Model treatment program utilized at this center. This is a twelve-step-based psychotherapy model. The two arms were matched in terms of Addiction Severity Index.

Sobriety was assessed one year after completion of the program, and the treatment group demonstrated 3x higher success rate than the controls (nominally 75% versus 25%). There was no dependence on drug of choice. Three-year follow-up confirmed the results obtained after the first year, as the experimentals successfully maintained their sobriety while the controls continued to succumb to relapse.

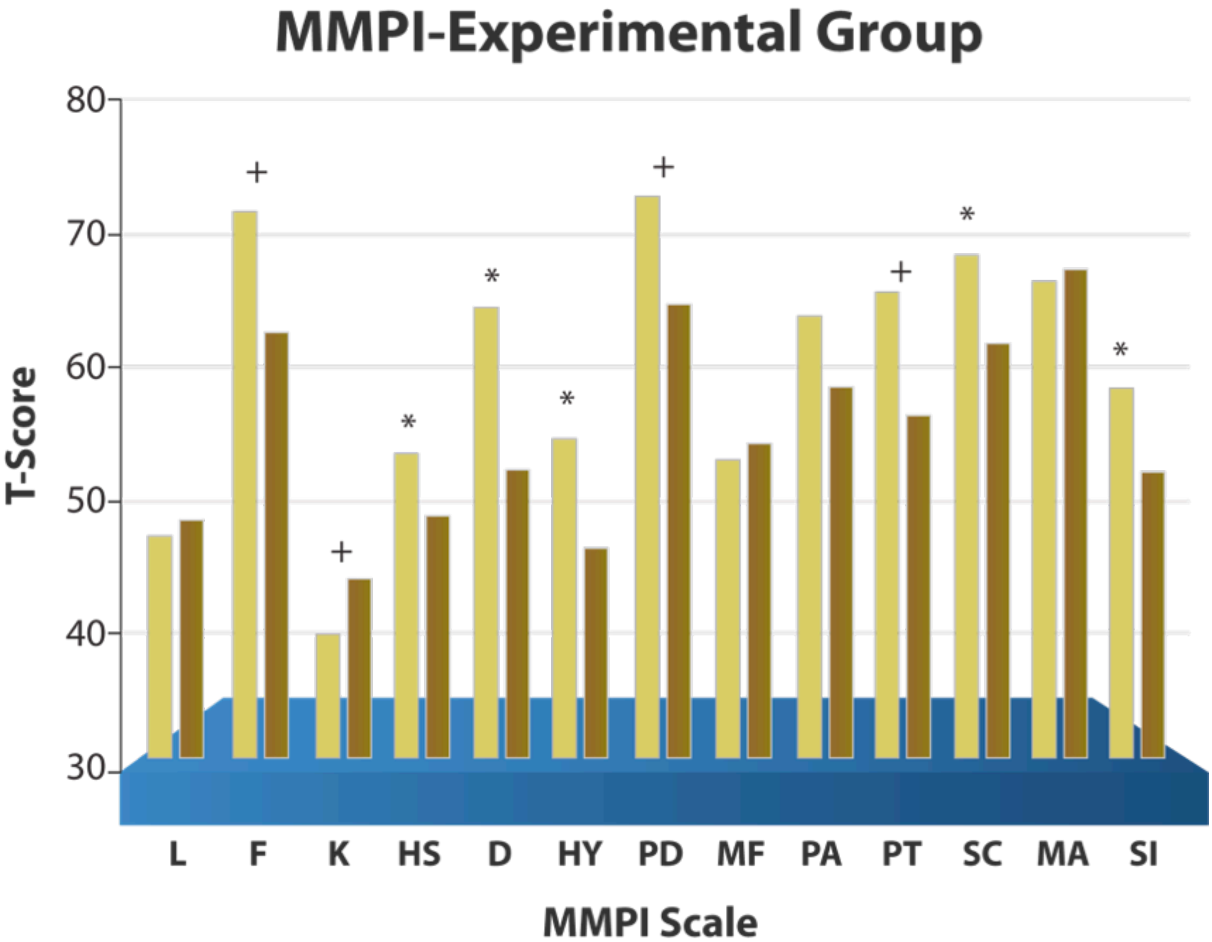

Figure 6. Pre-post results for the MMPI subtests. Stars indicates statistically significant treatment interaction, whereas the plus sign indicates that whereas the change observed was clinically significant, there was no significant treatment interaction. HS - hypochondriasis; D - depression; HY - conversion hysteria; PD - psychopathic deviate scale; MF - masculinity/femininity; PA – paranoia; PT - psychasthenia; MA - mania, and SI - social introversion.

Also, TOVA scores normalized only in the treatment group, and MMPI scores substantially normalized only in the treatment group. These results are shown in Figure 6. Five of the MMPI subscales improved significantly ($p < 0.005$): Hypochondriasis, Depression, Conversion Hysteria, Schizophrenia, and Social Introversion. Two additional subscales, Psychopathic Deviate and Psychasthenia, also improved but exhibited no significant treatment interaction because the control group likewise improved in these areas.

Retention in program held up much better in the treatment group than in the control group. In fact, it remained near 100% during the SMR/beta phase of the training. The EEG training had been done intensively at the beginning of the treatment program. By the end of the EEG training retention was at 98%, whereas for the controls it had already dropped to 74%. The trend in retention is shown in Figure 7. The study was completed (with the inclusion of the three-year follow-up) in 1998 (Ref. 7), and initial results were presented in 1999 in a poster at the American Association for the Advancement of Science annual conference. The study did not get published until 2005, after having been rejected by four journals (Ref. 20).

One is allowed to draw several conclusions from this study: Peniston's original findings were further supported; the modification of adding SMR/beta training had been worthwhile, although the costs of having dropped the temperature training component are unknown; and the improvements in the MMPI are suggestive of a much broader range of impact for EEG neurofeedback than had been originally envisioned. Perhaps the key to addiction is restoring mental function comprehensively, remediating psychic distress, and maintaining a euthymic ambient without the aid of drugs. Neurofeedback training conducted in a therapeutic context is the means to these ends.

It should be noted parenthetically that the history of rejection of neurofeedback papers served as a strong disincentive to organize publishable studies, particularly by clinicians who are not subject to the 'publish-or-perish' mandate, and who are utterly unprepared for the contentiousness of academia and the conservatism of editors and reviewers. Peniston's papers had all been rejected by American journals, and were therefore published in Canadian and Australian journals (Peniston 1989, 1990, 1991). The same held true for Michael Tansey's studies on improvements in IQ (Tansey, 1990). In consequence, none of them can be found on PubMed. Additionally, the Journal of Neurotherapy was never catalogued in Medline. For that reason, the bulk of the recent literature in neurofeedback remains part of the dark matter of the mental health universe. This is by no means unusual when it comes to the establishment of new paradigms. It has been said that "the history of modern science could be written on the basis of papers first rejected for publication."

"C3beta/C4SMR" training: various applications

In the late nineties the opportunity arose to evaluate the Othmer and Lubar Protocols in a public school system. Since the work was publicly funded, however, the school system retained control of the program, and political support at the school board level was only transient. Nevertheless, positive results were obtained that were subsequently reported (Ref. 8).

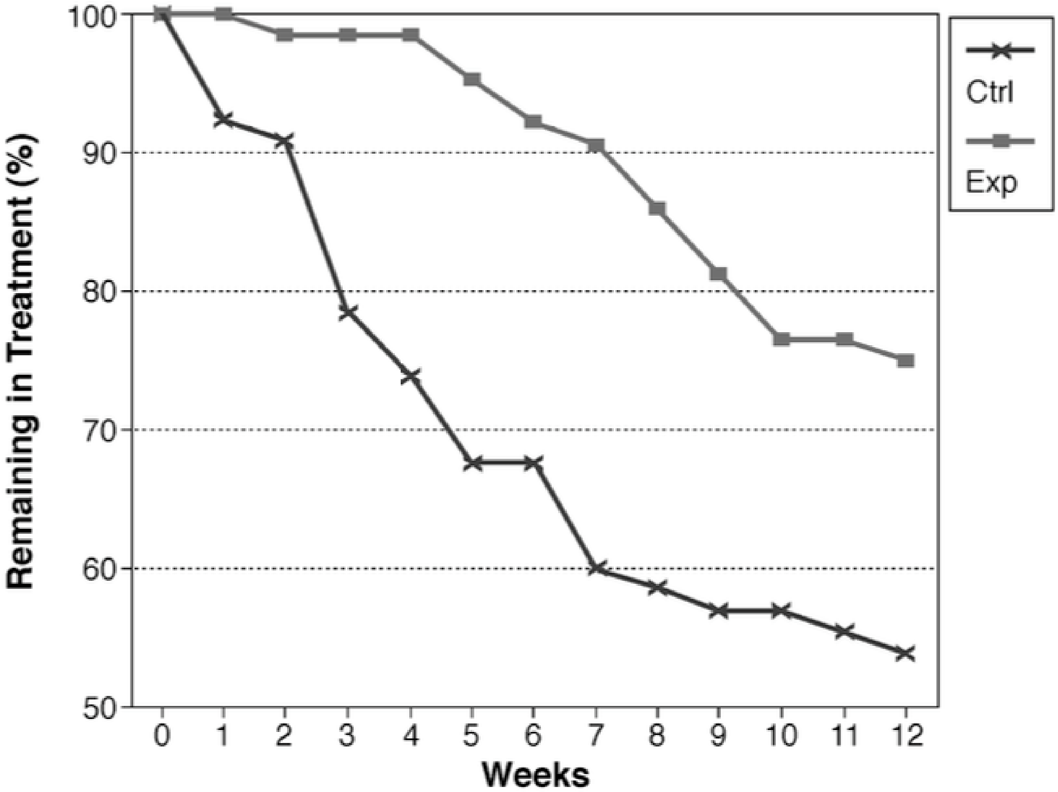

Figure 7. Retention in program for the two arms of the study. Retention remained high for as long as the EEG training was ongoing, which was in the range of four weeks.

Initial evidence that children on the autism spectrum could benefit from neurofeedback became available within our practitioner network in 1996, after several failed prior attempts. This led to a pilot study by Barbara Jarusiewicz that was published in 2002. The study yielded a modest average improvement of 26% in symptom severity over some 20 sessions (Ref. 10).

Some years later, autism was targeted more specifically by Rob Coben, who augmented protocol selection with digital EEG characterization (Ref. 25). Protocols were selected with the primary objective of moderating hyper-connectivity. This was done with single-channel bipolar montage, using primarily inter-hemispheric placements with tailoring of the reward frequency in the range of 5-16 Hz. The EEGer system, Othmer's second-generation instrument, was utilized in this study.

37 autistic children were compared with 12 wait-list controls. Average symptom improvement was 40% over nominally 20 sessions. 89% of the children responded to the training. There were no reports of adverse changes. 83% of controls reported no change in symptom severity.

In the practice of psychologist Matt Fleischman the opportunity presented itself to track gains in IQ score along with behavioral improvements in two identical twins of eight years who had been diagnosed mildly mentally retarded. Their response to the training had been a comparable 20-point gain, and by 2005 there had been five years of follow-up showing that gains were being maintained (although no further increase in IQ could be achieved with these same protocols). This work was rejected for publication by the Journal of Mental Retardation, most likely because of the deep-seated belief that changing IQ was not possible. The work was instead published in the Journal of Neurotherapy in 2006, where only the neurofeedback community itself would be aware of it (Ref. 23).

Formal evaluation of SMR/beta and Alpha-Theta Protocols

In 1999 Othmers taught their professional training course at Imperial College, London, at the invitation of Professor John Gruzelier, head of the Dept. of Psychology, and editor of the International Journal of Psychophysiology. The entire cohort of psychology graduate students was in attendance. This led to a number of studies based on our SMR/beta and Alpha-Theta protocols, and utilizing our NeuroCybernetics system, over the course of the next several years. A number of Ph.D. dissertations concerned themselves with this method, and launched the careers of a number of promising neuroscientists (Refs. 11, 12, 13, 15, 24).

The most significant and best-known reports was for a multi-year, multi-stage study to evaluate the utility of neurofeedback in the performance enhancement of students at the Royal College of Music. Although SMR and beta training were not found to be helpful in terms of musical performance, stunning results were achieved with the Alpha-Theta component of the study, as judged by blinded evaluators who were regularly recruited to evaluate student performance. Students advanced effectively one or two years in musical maturity with a mere ten sessions of A/T training for twenty minutes each (Ref. 12).

These results came about in an interesting way. In the first year of the research, participating students were placed either in the neurofeedback-only arm or in the group that underwent not only the neurofeedback but also the other supportive techniques normally offered to students, and consisting of mental skills training, physical exercise, and the Alexander Technique. There was also a control group that only received the standard supportive services. The neurofeedback-only group was the only one to show substantial gains in musicianship, as evaluated comprehensively. The results are shown in Figure 8. This raised the question of what happened with the comparison group that had also done the neurofeedback but showed no such gains. This then led to a follow-on study in which subgroups were each assigned to one of the supportive services exclusively. The results of the second study are shown in Figure 9.

This work led to a number of studies that further evaluated Alpha-Theta training, as well as additional studies on performance enhancement that utilized SMR/beta protocols. For a comprehensive review, see Ref. 24.

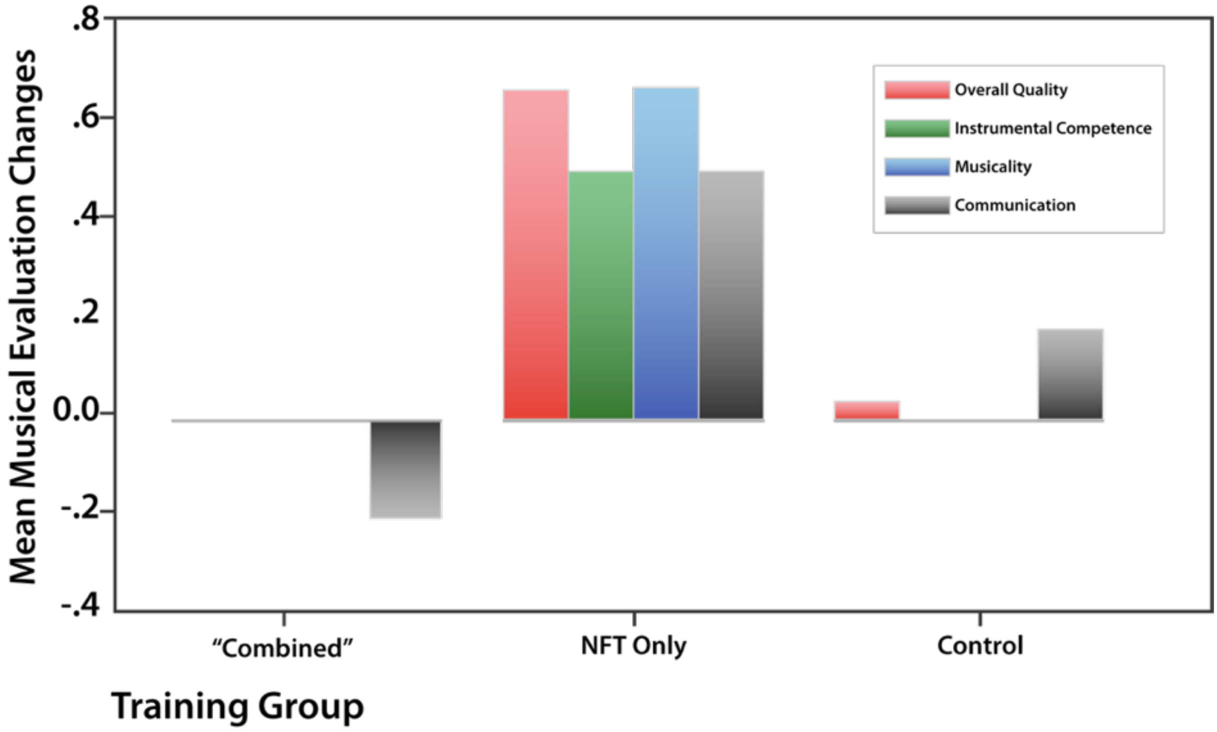

Figure 8. Outcomes in terms of the quality of musical performance are shown for the three arms of the study: 1) A neurofeedback-only group; 2) a group receiving both standard supportive services and neurofeedback, and 3) a group receiving only the standard supportive services. Positive outcomes in terms of the overall quality of musical performance were registered exclusively in the neurofeedback-only arm of the controlled study.

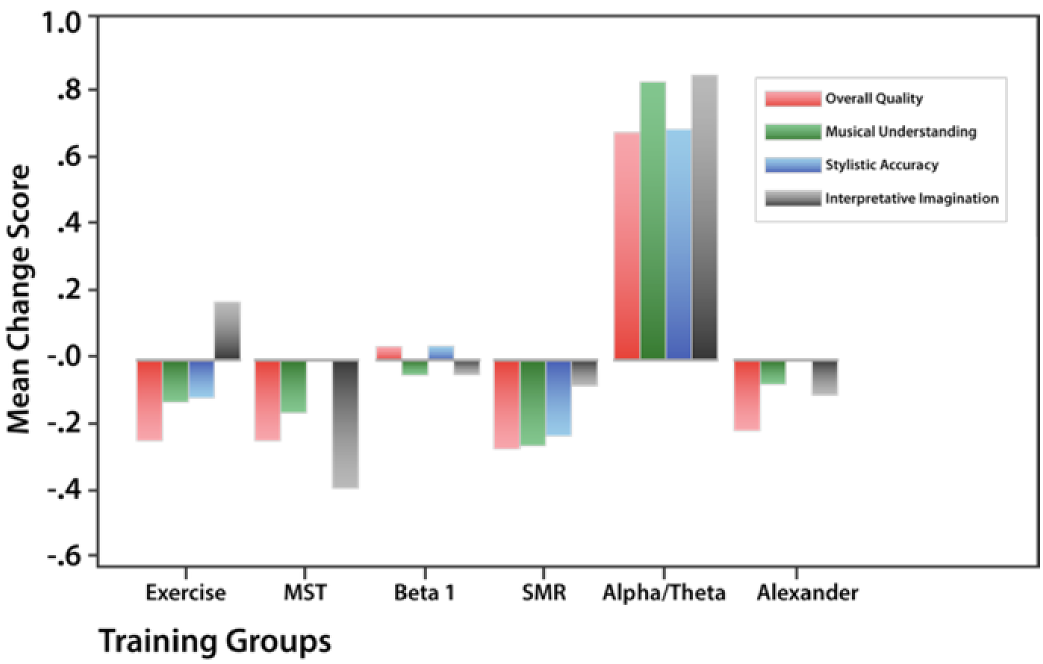

Figure 9. Results in terms of the overall quality of musical performance are shown for the standard supportive services and neurofeedback. MST stands for mental skills training. Only the Alpha-Theta training cohort showed gains in musical performance, and such gains were substantial and systematic. Musical improvements in overall quality was +14.4% (p= 0.06); musical understanding, +16.4% (p = 0.01); stylistic accuracy, +13.5%, (p =0.01); and interpretive imagination, + 17%, (p= 0.01).

The 1999 course at Imperial College launched yet another major line of research, under the direction of Andreas Müller of Switzerland. With clinical work ongoing at his clinic in Chur, a collaboration was undertaken with Dr. Juri Kropotov of the Institute of the Human Brain in St. Petersburg, Russia to establish a QEEG database that included ERPs. The database for children was established by 2003, and for adults by 2005. Some 1000 entries had been made by 2005, and the database contains some 1500 cases presently. This remains the only database available that evaluates ERP data. The main goal of subsequent research was to attain a better neurobiological understanding of human brain function, and more specifically to a broader search for neuromarkers. This work has led to a number of ground-breaking papers on mechanisms underlying ADHD. Dr. Mueller has published a book on ADHD in German, and Dr. Kropotov has authored two books on QEEG and Neuromarkers. Meanwhile, the clinical work of neurofeedback is ongoing at the Müller clinic in Chur.

Also in this time frame, Thomas Fuchs conducted a controlled study of the Othmer "C3beta/C4SMR" protocol---as realized in the NeuroCybernetics system---in application to ADHD for his dissertation research (Ref. 14). The comparison treatment was stimulant medication. 34 ADHD children were included in the program, with assignment to neurofeedback or stimulant medication according to parental preference. 22 children received thirty sessions of training for 60 minutes each, and 12 received stimulant medication. Outcome measures included the TOVA CPT, Child Behavior Rating Scales, and the WISC. The TOVA test results are shown in Figure 10. As in all other studies to date in which such comparisons have been performed (now six in total), the neurofeedback was shown to be comparably competent in managing the ADHD syndrome, as judged by evaluation with the TOVA. However, there were only slight gains in mean IQ score.

Two additional studies relate to this topic. The specific contribution made by the two constituents of the "C3beta/C4SMR" protocol to the lateralized attention networks was investigated by Eran Zaidel of the UCLA Dept of Psychology, on the basis of experimental

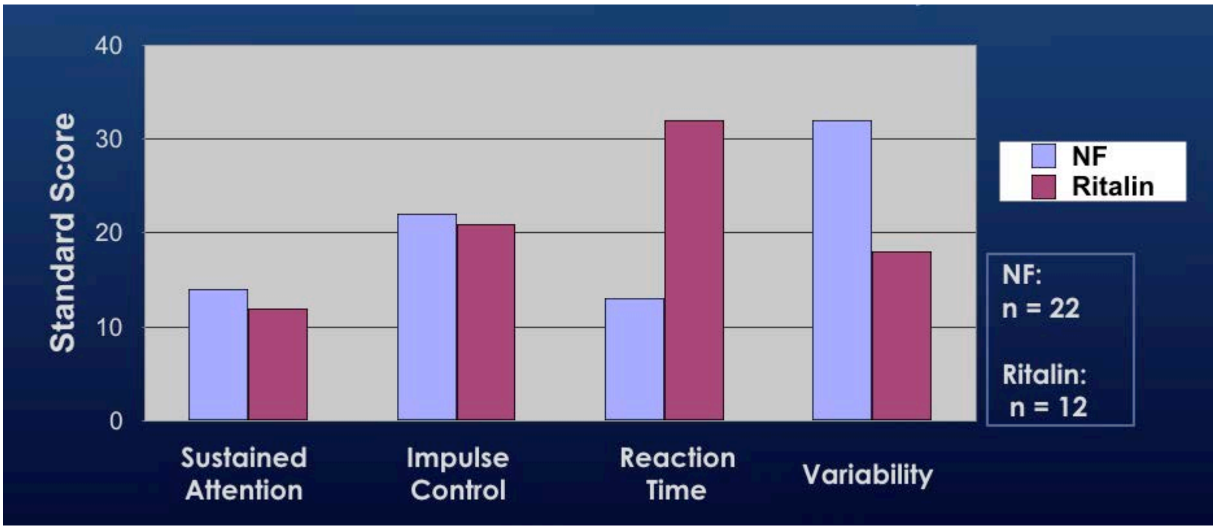

Figure 10. Results obtained by Thomas Fuchs in a controlled study comparing C3-beta/C4SMR protocols with stimulant medication (Ref. 14).

data furnished by Anat Barnea (Ref. 18). This work was published in 2004. In the following year, the effect of these protocols on lateralized word recognition was evaluated (Ref. 19).

More recently (2012), Andrew Hill tracked lateralized training effects of the "C3beta/C4SMR" protocol using ERP measurements along with behavioral measures, in the most comprehensive and exhaustive study on this topic done to date (Ref. 33). First of all, the Lateralized Attention Network Test (The LANT) was speeded up to present a greater challenge in this study (the sLANT). Further, high-resolution QEEG data were acquired not only for purposes of the ERP determinations but also to track changes during the EEG biofeedback sessions. Thirdly, a sophisticated capability for doing sham neurofeedback was established for purposes of this study. For verisimilitude, eye blink artifacts and other artifacts had to be imposed on the stored EEG recordings during replay. The subterfuge was completely successful, in that researchers were unable to distinguish between the sham and the veridical feedback.

Four protocols were evaluated: C3beta, C3SMR, C4SMR, and sham training. This choice permitted evaluation of frequency-specific effects at a given site (C3beta vs. C3SMR) as well as site-specific effects at a given frequency (C3SMR vs. C4SMR). Protocol-specific effects were noted on ERPs, EEG band activity, and on event-related spectral time series (time-frequency analysis). SMR and beta-band activity changed in all active groups, but not in sham. ERP changes were observed in sham as well. (After all, sham training is also an active process that engages the attentional faculties.) However, these changes were readily distinguishable from what was observed with the design protocols.

It was observed that EEG biofeedback could have a strong effect on hemispheric attention in as little as two sessions. Specificity of the neurofeedback protocols is strongly suggested by both the ERP and the behavioral (CPT) data. "The choice of electrode site appears to matter greatly, as does the choice of reward frequency."

Most surprising of all, event-related spectral changes could be observed within minutes of starting the training (Andrew Hill, personal communication). This measurement was possible because the rewards themselves give rise to event-related responses discernible in the EEG. Remarkably also, single-session effects on ERP components were documented.

This is highly significant in the following sense. The determination of optimum response frequency is made on the basis of felt change within the session, but such change consists in large measure of mere state shifts. There is no implication that significant learning is taking place on that time scale. Observations of rapid change in event-related spectral properties and in ERP components, on the other hand, must be interpreted as robust indices of functional adaptation taking place on that time scale as well.

Moreover, this body of work stands out in having performed perhaps the only unassailable sham-controlled study of SMR/beta neurofeedback to date. However, the fact that this was done with subtlety and finesse does not dispose of the inherent flaw in application to attentional deficits. As already indicated, sham training can engage attentional mechanisms nearly as effectively as veridical feedback.

Collectively this study has definitively answered numerous questions that continue to be asked about neurofeedback. Unfortunately, this dissertation, which was performed under the guidance of Prof. Eran Zaidel, has not yet been published in the journals.

Application to Various Diagnostic Categories

John Putman reported on the dramatic recovery of a female stroke patient with depression in 2001 (Ref 9). Also Alan Bachers published a report on a case of Cerebral Palsy and mental retardation (Ref. 16). This youngster undertook in excess of 200 neurofeedback sessions over the course of four years. Among other improvements, his measured WISC-III IQ score increased from 48 in 1998 to 72 in 2002. These cases are by no means isolated. In fact, stroke recovery, minor traumatic brain injury, and cerebral palsy were the principal focus of the clinical work with SMR/beta neurofeedback by Margaret Ayers, who first introduced Sterman's method into clinical work in 1975 and utilized these protocols over thirty years until her death in 2006. The early work merely lacked a pathway to publication.

Additionally, in this time frame Andrea Sime published a case study on the use of a combination of traditional biofeedback and neurofeedback for trigeminal neuralgia. The neurofeedback component utilized the Othmer protocols and instrumentation. It appears that the inter-hemispheric T3-T4 placement contributed critically to the clinical improvement (Ref. 17). This has since become the essential constituent of the protocol for trigeminal neuralgia, which behaves in training like other brain instabilities.

Adoption of Inter-hemispheric Training as the Default Protocol

In the time frame of 2004-5 nearly all of the Othmers' training in their own clinic was done utilizing inter-hemispheric placements at homotopic sites, involving principally T3-T4, C3-C4, P3-P4, Fp1-Fp2, and F3-F4. Normalization of the CPT with exclusive reliance on such protocols---singly or in combination---was demonstrated with the TOVA in a study published in 2005. In this report, Putman analyzed the CPT data from the EEG Institute in their entirety over the relevant time frame (Ref. 22). It was important to ascertain that nothing was being lost with the adoption of exclusively inter-hemispheric training over prior results.

In 2007 Petra Studer undertook a large-scale comparison of different neurofeedback approaches for her dissertation topic. Theta-beta neurofeedback, Slow Cortical Potential (SCP) training, and a version of the Othmer Method (here referred to as Adaptive Neurofeedback, ANF) were compared (Ref. 30). Studer constructed a protocol out of three elements of the Othmer approach: 1) Inter-hemispheric training at ({C3-T3} – {C4-T4}), with an optimization procedure starting at 12-15 Hz; 2) alpha-band synchrony training at P3+P4 centered on 10 Hz; and 3) optimized frontal/pre-frontal training with placements of ({Fp1-F3} – {Fp2-F4}). Results were comparable for all three protocols, with the ANF offering only a slight advantage in the emotional realm.

The range of ORFs was limited to the EEG spectrum in this study, even though by this time the Othmer Method had moved on into the Infra-low frequency regime. Also, visual feedback was by animation, so the very essence of the Othmer Method---continuous visual feedback on the dynamics of the reward-band signal--- was missing in this study. Hence this study cannot be seen as an evaluation of the Othmer Method.

The introduction of Infra-Low Frequency Training

By 2006 the Othmer Method was extended into the infra-low frequency region, which was accomplished by narrowing the signal bandwidth, and the protocol once again included lateralized placements for specific purposes. The first study testifying to the clinical effectiveness of the new low frequencies targeted Complex Regional Pain Syndrome. The results were collected for a sequential series of patients being treated at the UCLA Pain Clinic, under Joshua Prager, MD. The results were published in 2007; they either matched or exceeded the results achieved with fMRI feedback by Christopher deCharms in a study that had been published in 2005 (deCharms, 2005).

Extending the work to lower frequencies within the ILF regime required the design of new instrumentation tailored specifically to this application. Cygnet is the third-generation instrument that was designed to implement the Othmer Method. It became operational at the end of 2007 and has been the primary modality for all subsequent neurofeedback training by the Othmers.

Two case studies on the remediation of PTSD using the ILF protocols were published in 2009 (Ref. 27). These case reports made it apparent that the psychophysiological symptoms of PTSD could be reduced to clinical insignificance by means of the Othmer Protocol alone. This meant further that after the training the diagnostic criteria for PTSD could no longer be met.

By 2010 the results on the first 300 active duty service members that had been trained with ILF protocols became available for internal review at the military base where these results were obtained. The target was stress reactions, including PTSD, as well as traumatic brain injury. The vast majority of these service members qualified for re-deployment after the ILF training. The results of systematic symptom tracking have not been released to the public, but they testify to the effectiveness of the method in that utilization of the ILF protocols became the dominant modality in the Dept. of Deployment Health at this military base. By this time the Cygnet system had been optimized for the ILF application.

In 2009 Sebern Fisher authored a book chapter titled “Neurofeedback and Attachment Disorder,” on the basis of ten years of clinical work using predominantly the Othmer protocols with children suffering from developmental trauma (Ref. 28).

In 2010 the first publication appeared in which older Othmer protocols were used, in combination with other approaches, in the remediation of migraine in a compilation of some 37 migraine clients (Ref. 29).

In 2011 three case studies in which the ILF training procedure was used with pediatric epilepsy were published in the Journal of Child Neurology (Ref. 31). Also a case study of PTSD was described in the British Journal Pediatric Neurology and Psychiatry (Ref. 32).

In 2013 Carol Kelson performed a controlled study investigating recovery from PTSD of Vietnam era veterans being housed at a shelter for formerly homeless veterans. This study utilized the then-current ILF protocols and the Cygnet system. Fourteen veterans underwent the training, with the wait-listed control group receiving the training at a later date. The results were substantially positive, with particularly striking benefit for suicidality and panic (Ref. 35, 36).

And in 2016, a pilot study was published that likewise targeted the remediation of PTSD (Ref. 37). Curiously, the protocols utilized are in some respects a throw-back to the Othmer protocols that date back to about 2002-4. This is one of the few studies that utilized the optimization procedure, but the starting point was the SMR band, which had been the practice in those early years. Optimization was based on the arousal model that Othmers taught at the time. The study utilized the Othmers' second-generation design, the EEGer, which had been designed to implement this protocol. This study testifies to the fact that the early Othmer protocols are also still in active use by many practitioners.

Also in 2016 Jose Abara presented results showing single session training effects on the late Contingent Negative Variation, which applies in CPTs to the allocation of resources in preparation for an imperative stimulus. The late CNV was found to have greater negativity with respect to a neutral, no-feedback condition. The neurofeedback utilized in this study was infra-low frequency training (Ref. 38).

The latest publication by the Othmers (2016) features the summary results of all pre-post CPTs that had been accumulated on a central server by 2014 (Ref. 38). The accumulated data set included 5,746 pre-post analyses that bracketed nominally twenty sessions of mostly ILF training. Hundreds of clinicians from a number of countries contributed to this data set. Hence it is representative of current clinical use of the method, which does not consist of ILF training exclusively. The data set included all diagnostic conditions being treated as well as those who simply undertook the training to enhance performance.

The result of the compilation was to demonstrate a substantial move toward performance above norms in all measured categories. This held true particularly for impulsivity, where normative behavior leaves substantial room for improvement. The CPT utilized in this study was the QIKtest, which was developed in 2005 as a replacement for the TOVA (Ref. 40). New norms were developed for the QIKtest in 2014 to replace the TOVA norms that had been used up to that time, and the analysis was performed using these updated norms.

Results for impulsivity are shown in Figure 11 for the entire set of pre-post data up to 2014, some 5,746 cases. There were no exclusions. There is a pronounced trend toward scores above norms. Significantly, the degree to which norms are exceeded increases monotonically with score. Similar characteristics are observed on the deficit side: the relative improvement increases monotonically with increasing (worsening) levels of deficit.

The deficited portion of this distribution is shown in Figure 12. Here the pre-training data are shown as a cumulative distribution for those scoring less than 85 at the outset (16th percentile). After training of nominally twenty sessions, the cumulative distribution shows 30% to be scoring above norms, with only one-third of the pool still scoring less than 85. The effect size is approximately one standard deviation. It should be noted that the potential benefits of the training have not been exhausted by twenty sessions, particularly among those still scoring in deficit.

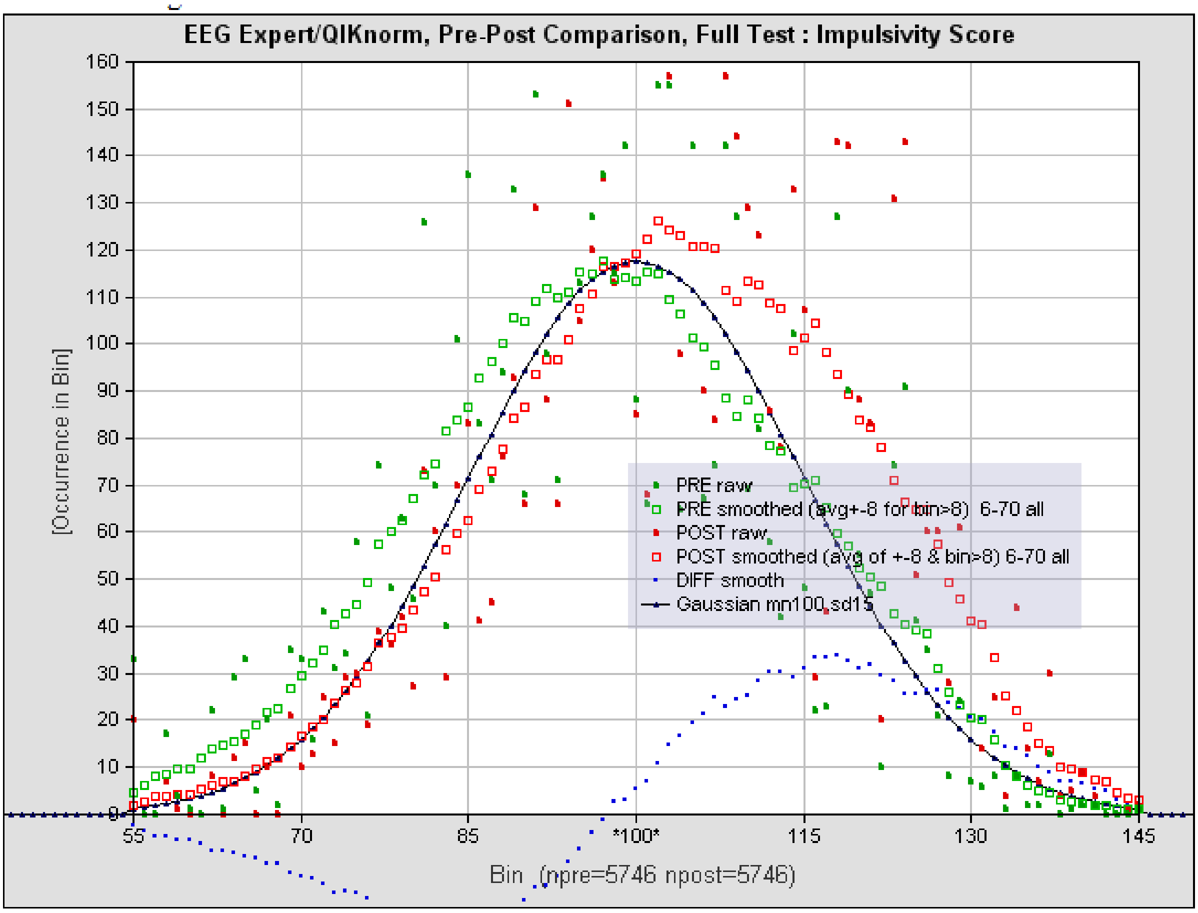

Figure 11. Comprehensive compilation of pre-post impulsivity measures from the entire practitioner network that utilizes the QIKtest for CPT analysis. The data cover the time period of 2006 to 2014, and thus includes mainly results obtained with infra-low frequency training. The pre-training distribution is shown in green. The post-training distribution (obtained after nominally twenty sessions) is shown in red. The normative distribution is shown in black. The data have been smoothed by means of near-neighbor averaging for enhanced clarity.

In addition to the outcome studies briefly outlined above, outcomes were also tracked internally at the EEG Institute over the years. For example, CPTs have been performed on all clients capable of taking the test since 1990. This consistent tracking gave confidence that nothing was being lost as changes were being introduced into the protocol. A review of the summary data over the period of development of the ILF training procedure can be found on the Assessment section of our website, www eeginfo.com (Ref. 41).

Recently, a re-analysis of the contemporary CPT data at the EEG Institute was performed with exclusion of non-responders, for purposes of comparison with the conventional analysis (Ref. 34). The results for errors of omission is shown in Figure 13 for those scoring less than 85 at the outset, rank-ordered by initial score. Here some 24% of cases were removed as non-responders. The remaining data make it apparent that the likelihood of recovery of full functionality (i.e., zero omission errors) is essentially independent of the level of initial deficit. Moreover, 54% of responders reach this performance limit. This is a remarkable observation.

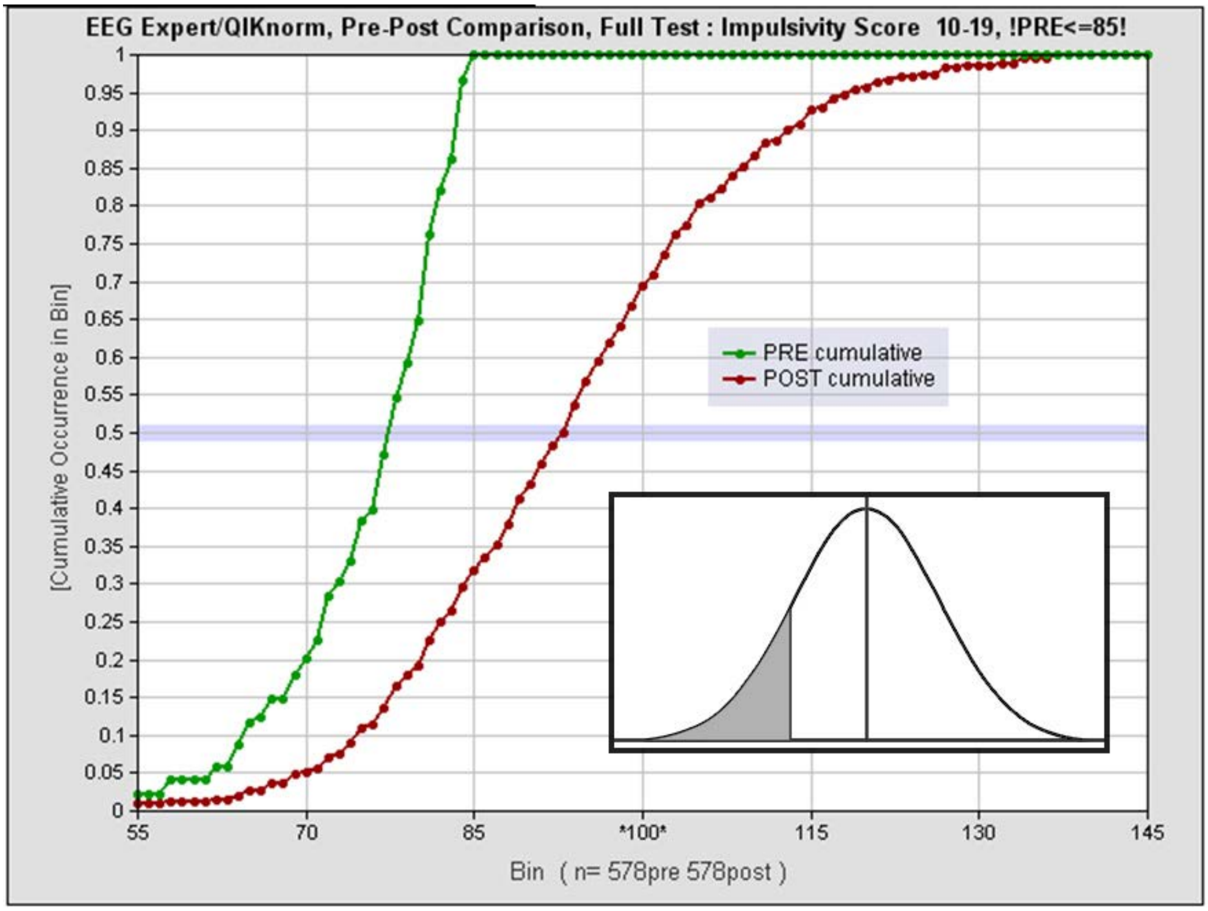

Figure 12. Plotted here is the deficited portion of the data set of Figure 11. Shown in green is the cumulative distribution for those scoring at less and 85 in standard score at the outset (16th percentile). Shown in red is the cumulative post-training distribution. What started out as 6.25 times the normal population below 85 (i.e., 100% versus 16%) ended up only two times the normal population (32% versus 16%), a substantial degree of normalization. Fully 30% ended up scoring above norms.

Something very similar is observed for impulsivity. The data are shown in Figure 14. The likelihood of scoring at or above norms is only modestly dependent on the level of initial deficit. The immediate implication for purposes of research is that effect size is not an appropriate measure. In fact, it has been obvious from the earliest compilations of CPT data that the effect size is a strong function of the initial deficit in the population (see Ref. 41). The pattern is also evident in Figure 5. Effect size is therefore an unsuitable measure to quantify clinical effectiveness. One might also observe that no placebo behaves like this, which renders placebo-controlled studies superfluous.

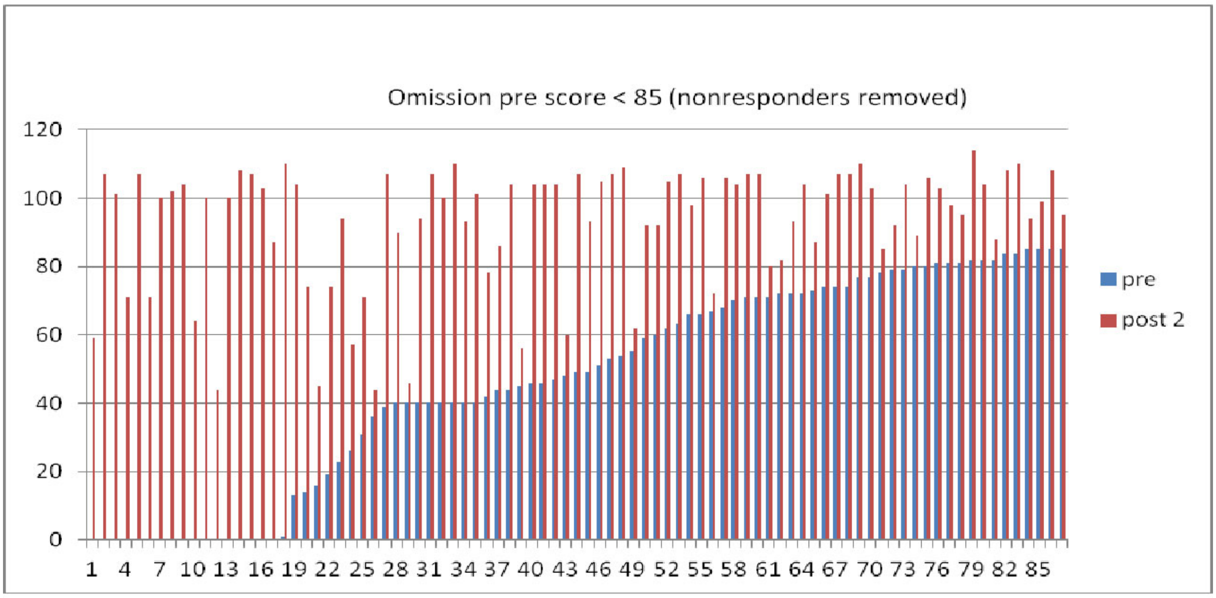

Figure 13. QIKtest results for errors of omission are shown for the client population at the EEG Institute. Cases are plotted rank-ordered by initial score, and only those scoring 85 or less at the outset are illustrated. This amounted to 87 cases from a larger pool of 350. For illustrative purposes non-responders are not shown. All those improving by less than five points were assigned to the non-responder category. This amounted to 24% of the total pool. The plotted data illustrates the observation that the recovery of full functionality (i.e., zero omission errors) appears to be achievable with comparable likelihood irrespective of the initial score.

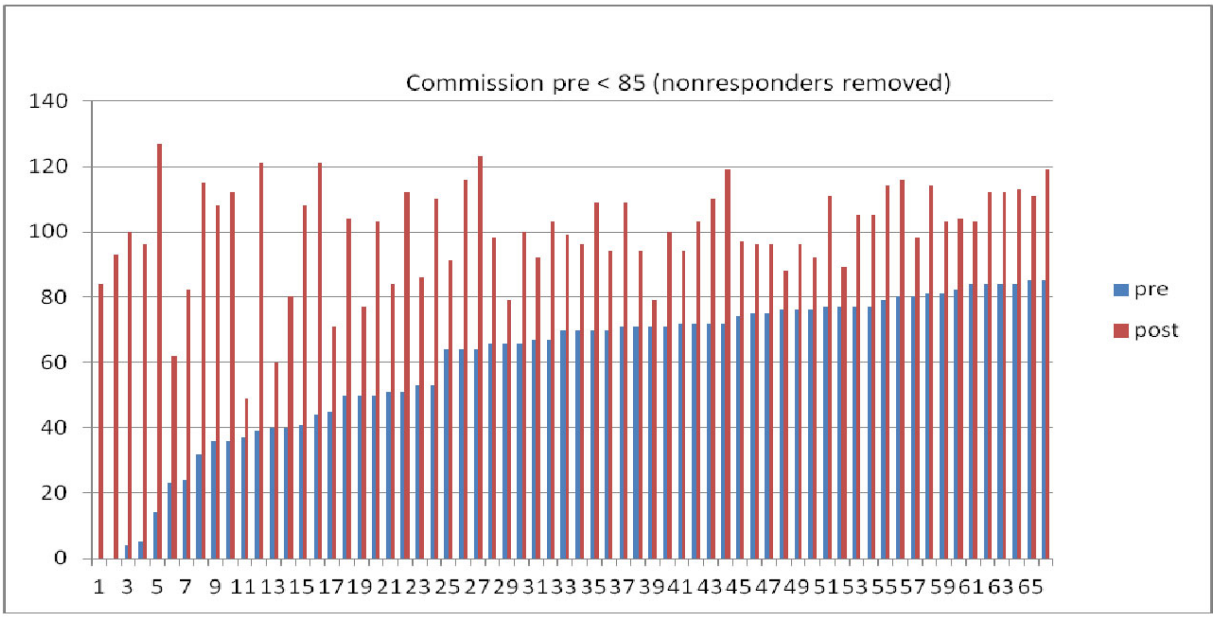

Figure 14. QIKtest results for errors of commission are shown for the client population at the EEG Institute. Data were treated similarly as in Figure 8. Non-responders amounted to five percent of the pool, and were excluded from the plot. 67 cases are shown. The plotted data illustrate the observation that the recovery of functionality is only modestly correlated with initial score.

The Elucidation of Mechanisms

Internal research at the EEG Institute has been directed throughout toward refinement of the method and toward a better understanding of the mechanisms involved. There are first of all the issues relevant to all of neurofeedback with respect to the means by which the brain effects its remedies. With infra-low frequency training there is the additional question of just how the brain responds so profoundly, and so promptly, to slowly varying signals. The conventional understanding of the limits of signal processing appear to be violated. These issues are addressed in a comprehensive treatment published in 2013 (Ref. 34).

In brief, the brain is reacting to the dynamics of the low-frequency rhythmic activity, and these dynamics are available in real time without delay, albeit with substantial attenuation due to the filtering operation. Significantly, the brain is merely observing a correlate of its own activity. It is not an outside observer of the signal. It is a matter of recognition rather than of detection. In consequence, the brain's sensitivity to what is transpiring on the screen and in the audio stream is vastly greater than that of an independent observer. These two factors suffice to open up the infra-low frequency regime for training.

There has also been an evolution in the theoretical understanding of neurofeedback. The ILF training is best understood at the systems level as an appeal to core regulatory function rather than as a tool of remediation for specific deficits---even though the latter may well resolve in consequence of the former. The entire orientation is toward the enhancement of functional competence, as reflected both in the amelioration of functional deficits and in the augmentation of positive attributes. In that perspective, the entirety of the body of research can be seen as supportive of the core claims of the method to one degree or another.

The training is mechanisms-based, and therefore places principal reliance on standard protocols. These are based on considerations of functional neuroanatomy and functional imaging and then have to survive empirical validation. The central thread that connects the various protocols is the concept of the optimal response frequency, the ORF. Frequency rules have been discovered through the clinical work that establish a fixed relationship between the ORFs for left-lateralized, right-lateralized, and inter-hemispheric placements, as well as between the frontal/pre-frontal, the central, and the parietal/occipital inter-hemispheric placements. These relationships are illustrated in Figure 15 for lateralized training. These rules are operative without clear exception across five

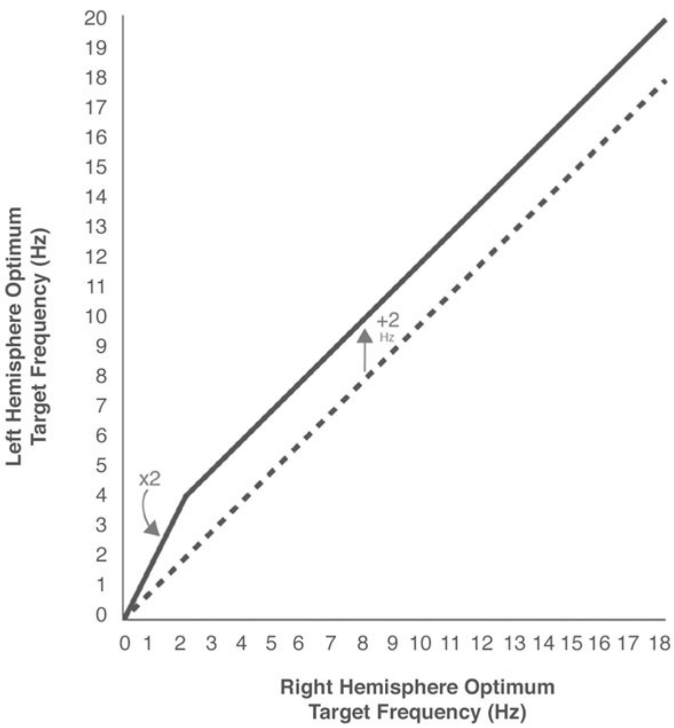

Figure 15. Shown here is the frequency relationship that relates the optimum target frequency for left-hemisphere training loci to the optimum target frequency for right-side placements. This relationship has been relied upon for the optimization of clinical outcomes for nearly twenty years, and it is being continually confirmed in the practices of about 5,000 clinicians.

orders of magnitude in frequency. The existence of these rules points to an underlying organizing—and unifying—principle that implicitly validates the entire construct that has been given empirical support in the collective work.

Significantly, inter-hemispheric placements optimize at the same frequency as right-lateralized placements. This allows one to argue for right-side priority with respect to the organization of core regulatory function. This is in line with the protocol hierarchy that has emerged, which likewise prioritizes right-hemisphere and inter-hemispheric placements.

The very existence of frequency rules eliminates the placebo as an explanatory model. After all, the ORF determination is based entirely on the subjective reporting by the client, who is blind to the target frequency that has been selected. With the placebo model ruled out, no justification remains to mandate placebo-controlled studies as part of a validation procedure for the Othmer Method. Further, given the individualization of protocols and the heterogeneity of the patient population that this signifies, there is no obvious role for frequentist analysis of group-based studies. The dimensionality of the space in which the Othmer Method operates does not lend itself to narrowly targeted studies. The validation procedure for the Othmer Method has therefore been largely Bayesian.

Bayesian inference connects findings across time. Hence it is appropriate for frontier science, and for exploratory development that takes an evolutionary path. It is frankly the only realistic option for clinical research conducted in the private practice setting with prevailing ethical constraints. Specifically, at every point in a clinical case trajectory, it is obligatory to do what is in the best interest of the client at that moment. There can be no competing agendas. At every point along the way, the operative question is whether what is being done presently is better than what was being done before. The training is done in an atmosphere of contingency. Protocol choices are continuously being weighed. This scaffolding approach is taken with every client in every training. A research discipline therefore applies at the level of the individual client at every session, at the level of the EEG Institute clinic, and at the level of the entire practitioner network. There are no fixed stars in the firmament to which one could attach the definitive study.

Summary and Conclusion

The collective research concisely summarized above has yielded formal support for the critical aspects of the Othmer Method of EEG neurofeedback: the adoption of dynamic feedback for self-recovery; reliance on the optimization procedure in the frequency domain; and the sequencing of protocols according to the developmental hierarchy. Validation of the method is furnished by the internal tracking of results within the EEG Institute and throughout the practitioner network. The concept of the ORF, along with the frequency rules, confers a conceptual unity onto the entire enterprise.

The essential departure of the current method is that it relies almost entirely on the brain coming to terms with its own EEG and its Slow Cortical Potential. The training is predominantly non-prescriptive. The signal can therefore be delivered covertly, which is what happens in practice. This means that the trainee need not even be aware of the fact that training is occurring. No conscious demand is placed on the trainee.

In sum, then, we are concerned here with an autonomic—i.e., non-volitional—self-regulatory process in all of its aspects. In this venture the brain depends upon information rather than instruction. There is little or no external agency. The provocation for change emerges out of the dynamics of the brain engaging with its own real-time signal. Since the orientation of the method is almost entirely one of promoting functional integrity rather than the expunging of deficits, such deficits need not be discerned at the outset nor specifically targeted. It has also become quite evident that the training addresses itself broadly to regulatory competence, and is therefore applicable to the entire regime of mental function and of dysfunction. To the extent that the brain is also involved in the regulation of so-called 'peripheral' physiology, the training has profound implications for health care in considerable generality.

Post-Script

The reader may wonder how such an extensive body of work, one that is certain to revolutionize the entire realm of mental health, could be traceable in the main to a single clinician, Sue Othmer, and to her clinical and technical team. The fact is that even though Sue Othmer has been the clinical catalyst over a period of some thirty years, progress was contingent on developments in the instrumentation area, in signal processing, in testing procedures, in professional training, and in large-scale clinical validation. A tight feedback loop has always existed between clinical evaluation and technical development. Another feedback loop involved the practitioner network, which not only furnished 'proof of practice' but also became the source of important new observations, an early version of 'crowd-sourcing.'

Additionally, development rested upon the research foundation laid by the pioneers of the field: Joe Kamiya, Barbara Brown, Elmer Green, Lester Fehmi, Jim Hardt, Tom Budzynski, Barry Sterman, Joel Lubar, and Niels Birbaumer in the first generation; Patricia Norris, Eugene Peniston, Margaret Ayers, David Kaiser, and Ute Strehl in the second. They all left identifiable imprints on the method. Collectively the development effort relative to the Othmer Method has consumed an estimated 140 man-years since the Othmers started in 1985. The financial resources committed to the research and development come to around $20M. This does not count the contributions by those who researched the methods using their own resources.

Success is also due to all of the early adopters who persisted in pursuing this new approach despite any misgivings of peers, colleagues and family. The practitioner network utilizing the Othmer protocols is the largest such network devoted to a particular approach, and that has been the case for two decades. A world-wide practitioner network of some 4,000 clinicians is now relying primarily on the ILF training for their neurofeedback–related work. Essentially all of these came to neurofeedback from other career paths, and many of them had prior exposure to other methods of neurofeedback, including prior versions of the Othmer Method, before taking up the ILF training.

Finally, success is owed to the many lay people who trusted their own judgment against that of their doctors and others, and allowed their children to be trained with neurofeedback. The EEG Institute is now seeing the children of those first trained two or more decades ago. By 2016, it can be estimated that more than one million individuals have benefited from Othmer protocols over the years. Presently some 500 people are thought to be graduating every week from ILF neurofeedback training.

The critical advantage of the Othmer Method vis-à-vis academic research in neuroscience is that it places the brain in the loop with continuous feedback on its own activity. The brain is functioning as the detector. The signal is not the subject of study per se. Rather, the subject of interest is the real-time response of the brain to its own signal. The method called for is 'observational science,' for which academic research has neither the inclination nor the opportunity. Observational science, in the manner of Nikolaas Tinbergen and Konrad Lorenz, can only flourish in the rich, varied, and complex clinical world, from which consistent patterns of responding are discerned over time. What set Sue Othmer apart from others in the field is her adoption of this 'bottom-up' approach to the technical refinement and evolution of the method that began with Barry Sterman, Joel Lubar, Michael Tansey, and Margaret Ayers.

The significant advantage vis-à-vis academic research in neurofeedback is that the Othmer Method has moved beyond the operant conditioning model. Academic research in neurofeedback, on the other hand, is still largely based on that model of efficacy. Hence the studies are typically conducted with relatively primitive instrumentation and by relatively untutored researchers. Additionally, neurofeedback is researched as a fixed 'procedure' in which clinical intelligence is regarded either as superfluous or as a confound, so that adaptation of the protocol to the trainee is not an option. And finally, academic research is typically still trying to contend with the placebo model, so the real issues are not even being addressed. It is quite plain that this paper could not have been written if neurofeedback were reducible to a placebo. Moreover, the placebo model is frankly a scientific relic that should have no place in the age of neuroscience. It is a case of Skinner's "explanatory fiction," which is intended to "allay curiosity and bring inquiry to an end." We are, instead, at a promising beginning.

Acknowledgements

Special acknowledgement is due the engineers and software developers who have made all of these discoveries possible. First and foremost, recognition must be given to Tim Scully, a pioneer in EEG instrumentation design and manufacture. He was surely the first to display the two-channel EEG as a Lissajous loop using a helium-neon laser in 1972—just for his own amusement! For the first generation system (1987 to the present), the NeuroCybernetics, special thanks are due to Edward Dillingham for the software development, and to Tim Scully and later John Picciottino for the hardware design and fabrication. For this project, Dillingham drew on his prior experience in the development of analog systems for sonar detection. For the second generation EEGer system (2002 to the present), special thanks are due to Howard Lightstone, whose background included the development of real-time software for the simulation of missile systems at Lockheed Aircraft.

For the third-generation design, the Cygnet (2007 to the present), special thanks are due to Bernhard Wandernoth, Ph.D., whose prior work included the design, development, and construction of the first ultra-high-speed laser communications system for the European Space Agency. After seven years of intensive in-orbit testing, this technology became the basis for the first such system in commercial use.

Each of these engineers was persuaded at the outset of the enormous potential of neurofeedback to aid human health and well-being. Their personal trajectory stands as powerful testimony to the proposition that the scientific world is moved forward by inquiring minds and eager engineers rather than by naysayers and skeptics. Progress is actually hindered by those who seek the limelight to apprise the world of their abiding skepticism. (Among the unfairnesses of our human existence is that engineers rarely get the credit; lawyers rarely get the blame; and skeptics rarely pay a price for impeding progress.)

Special acknowledgement is also due to John Putman, who performed all of the analyses of CPT data from the EEG Institute over the years, and to Marco Versace, who created the program EEG Expert for CPT analyses on the TOVA and the QIKtest, along with the symptom tracking program.

Aphorisms and Pithy Observations

"Bottom-up thinkers try to start from experience and move from experience to understanding. They don't start with certain general principles they think beforehand are likely to be true; they just hope to find out what reality is like. If the experience of science teaches us anything, it's that the world is very strange and surprising. The many revolutions in science have certainly shown that." John Polkinghorne

"The history of science is rich in the example of the fruitfulness of bringing two sets of techniques, two sets of ideas, developed in separate contexts for the pursuit of new truth, into touch with one another." J. Robert Oppenheimer

"'It is necessary for the very existence of science that the same conditions always produce the same result.' Well, they don't. It is necessary for the existence of science that minds exist which do not allow that nature must satisfy some pre-conceived conditions like those of our philosopher." Richard Feynman

"He who studies medicine without books sails an uncharted sea, but he who studies medicine without patients does not go to sea at all." William Osler

"Those who insist that there is not a shred of evidence are usually the ones shredding the evidence. Findings are not invalidated for having been discovered in unconventional means." Siegfried Othmer

"First the findings; then the science." Elmer Green

"Give the brain any information about itself and it will make sense out of it." Paul Bach-Y-Rita.

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