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WECHSLER (WISC-R) CHANGES FOLLOWING TREATMENT OF LEARNING DISABILITIES VIA EEG BIOFEEDBACK TRAINING IN A PRIVATE PRACTICE SETTING

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Abstract: This paper presents Wechsler (WISC-R) profiles and changes following the application of an EEG biofeedback treatment regimen for brain-based learning disabilities. EEG biofeedback trained increases in activation (increased amplitude of 14Hz brainwave energy) of the central and sensorimotor cortex's neural activation network resulted in increases in bi-hemispheric skills (complementary verbal-expressive and visual-motor abilities) prerequisite to a successful learning posture, the acquisition of reading and integration of higher-order learning. Enhanced/normalized academic, physical, psychophysiological, abilities were reflected in changes in brainwave energy signatures and WISC-R data. Brainwave signatures and WISC-R profiles "normalized" as a result of training with significant remediation of learning disorders. There was significant growth in WISC-R Full Scale, Verbal, and Performance IQ scores, reflecting improved brain function and resultant test performance, with a "normalization" of Verbal-Performance IQ anomalies. An inverse relationship was observed between energy levels at 5Hz and 7Hz and pretreatment FSIQ levels. Classic Bannatyne patterns were found to be representative of the learning disabled with pretreatment FSIQ scores within the low-average to high-average intellectual ranges.

Child clinical psychologists are trained in assessment, psychotherapeutic and intervention skills. We operate as informed therapeutic professionals. Yet, until very recently, when dealing with the learning disabled, while we could assess the integrity of brain function, social skills, academic and intellectual status, etc., we could not impact on the learning disabled child's impaired brain function; of which the learning disability was merely a reflection. With EEG biofeedback training, it is possible to go beyond supportive psychotherapy and utilize a therapeutic medium within which we may directly impact on the brain state characterizing learning disabilities.

The first laboratory based group to use EEG biofeedback for working with hyperkinesis (Lubar & Shouse, 1976; Shouse & Lubar, 1979) pointed the way. The literature on private practice based EEG biofeedback training for the remediation of brain based learning disability is severely limited. Tansey & Bruner (1983) reported the first successful application of a clinical, ***private practice based***, EEG sensorimotor rhythm biofeedback training regimen for the treatment of learning disorders. Over the past eight years, I have published on the positive impact of this clinical, office-based regimen, for brainwave energy realignment/normalization, on a wide variety of disorders; including asthma (Tansey, 1982), hyperactivity concurrent with a developmental reading disorder and oculo-motor-vestibular dysfunction (Tansey & Bruner, 1983), learning disabled with

diagnoses of Neurologically Impaired (NI), Perceptually Impaired (PI), and learning disabled with Borderline FSIQ levels (Tansey, 1984; Tansey, 1985a), Petit Mal epilepsy (Tansey, 1985b); Giles de la Tourette's Syndrome (Tansey, 1986), and most recently with twenty-four youngsters (11 PI, 11 NI, 2 ADD) with brainwave signature patterns reflective of a brain-based learning disability (Tansey, 1990).

Historically, hyperactivity and learning disabilities, with or without concurrently manifesting perceptual-motor and/or verbal-expressive deficits, have been attributed to ongoing underactivation of a medial bilaterally organized premotor system (SMA) and more generally the sensorimotor (Rolandic) cortex. Such reporting of "underactivation" of a medial bilaterally organized premotor system (SMA) for hyperactives via EEG brainwave monitoring (Tansey, 1983, 1984, 1985, 1990) has recently received independent verification in the New England Journal of Medicine's November 15, 1990 issue. Therein was presented evidence of frontal hypometabolism in hyperactives - significant global and regional reductions of cerebral glucose metabolism; with the largest reductions in the pre-motor cortex and superior pre-frontal cortex (Zametkin, Nordahl, Gross, King, Semple, Rumsey, Hamburger & Cohen, 1990).

Lubar, Bianchini, Calhoun, Lambert, Brody & Shabsin (1985) and Tansey (1984, 1985, 1990), while pursuing distinctly different treatment methodology, in different clinical settings, utilizing different electrode types, sizes, and electrode placements, report mutually corroborating findings of consistent patterns for amplitudes of various brainwave bands for the learning disabled. Notably, the learning disabled present with significantly higher amplitudes of brainwave activity in the 7Hz "Theta" band than in the 14Hz "sensorimotor" band. Such reports point to how EEG biofeedback data (brainwave signatures) plus WISC-R profiles can be used to maximize the diagnostic efficacy of the psychologist/biofeedback clinician's contribution to a truly comprehensive learning disability evaluation and effective treatment plan.

The Purpose of this paper is to further describe the clinical features of children who had their learning disorders successfully treated via EEG biofeedback training (Tansey, 1990); with an additional emphasis on Wechsler changes reflecting the remediation.

METHOD

Subjects

The subjects (Ss) were 21 boys and 3 girls, each with a history of learning disabilities whose parents chose to have their learning disabilities treated with EEG biofeedback training. All children presenting with learning disabilities in my practice, and whose treatment was completed in time to be included in this study have been included. There was no further subject selection. All children so treated with the following technique to date of publication are included in this study. Eleven subjects were primarily diagnosed ***by their child study team*** as Neurologically Impaired, eleven Perceptually Impaired, and two with diagnoses of attention deficit disorder. They ranged in age from 15yrs. 6 mos. to 7 yrs. 4 mos. . Their mean WISC-R IQ scores were as follows: Verbal 98.8 with a SD of

16.2 and a range of 72 to 128, Performance 98.1 with a SD of 16.9 and a range of 72 to 131, and Full Scale 98.3 with a SD of 16.5 and a range of 70 to 126.

Five manifested Verbal-Performance IQ score discrepancies in favor of the Performance IQ from 12 to 31 points (Cases 2, 4, 12, 20, and 21). Five manifested Verbal-Performance discrepancies in favor of the Verbal IQ from 13 to 21 points (Cases 5, 6, 8, 22, and 24). The remaining fourteen varied between 0 and 11 points, with four not exceeding 1 point difference. Their pre-EEG biofeedback training "brainwave signatures" (Tansey, 1985, 1990) showed a 211% greater amount of energy reflected in the Theta (7HZ) band than in the 14Hz brainwave band.

Apparatus and Procedure

EEG biofeedback training of the 14HZ brainwave rhythm was conducted in weekly, 40 minute training sessions. A single channel Nova Systems"Tansey Ten" Biofeedback EEG was used to assist the subjects in orienting on the 14HZ (24db per octave rolloff) neural discharge rhythm over the central Rolandic cortex. The monitored 14Hz neural discharge (brainwave) signal was protected, via filtering, from contamination by alpha and low-amplitude scalp EMG. At 24db the filtering offered adequate signal protection. For example, while processing the feedback tone reflecting the 14Hz brainwave band, a 7HZ signal would have to be 25 times larger in amplitude than the 14HZ signal to affect the feedback loop. Stated another way, 4% variation in the processed 14Hz filtered signal may be attributable to the 7HZ contamination. As past research with this procedure has shown, increments in 14Hz amplitudes are associated with decreases in 7HZ amplitude levels in any event. At 24db, filter ringing is not reported by Nova Systems to be a factor for concern.

In monitoring 14Hz brainwave production, three Nova Systems saline sensors were used (impedance in saline of 1K ohm). To monitor, and subsequently train, bilateral 14Hz discharge patterns, the active sensor was placed so that its 6.5 cm x 1.3 cm contact surface lay lengthwise along the midline of the top of the skull (overlaying the cerebral longitudinal fissure), centering about 2.6 cm behind CZ (10/20 system). It is held in place with two elasticized headbands with Velcro on the ends. One band is placed about the head, parallel to the eyebrows, across the middle of the forehead. A second band goes across the top of the head and the active sensor, attaching at either end on the other headband, near each ear. In this position, the active sensor is kept in place and centers over the Rolandic cortex (pre- and post-central gyri) of both the right and left cerebral hemispheres; extending anteriorly over the upper portions of the bilateral Supplementary Motor Area (Goldberg, 1985). The reference and ground sensors are randomly placed on opposite ears via comfortable earclips.

The monitored 14Hz brainwave signal was then automatically transmitted through the electroencephalograph for ongoing signal processing and subsequent auditory feedback. The single channel "Tansey Ten" EEG unit provided both amplitude and frequency modulated feedback. The feedback tone was modulated so that the greater the amplitude of the brainwave, the louder the tone. In addition, the repetition rate of the tone (number

of beats per second) co-varied with the rate of occurrence of the monitored brainwave energy as it exceeded threshold (set a 3 microvolts Peak-to-Peak). For all subjects, the EEG signal/signature spectrum was subjected to on-line computer analysis with a PC (my ongoing studies are now using the NeXT computer which incorporates a built in digital signal processor for fast-Fourier transforms of all EEG data in the 0 to 90Hz range).

Evaluations of changes in the mean 14Hz brainwave rhythm amplitude (energy) were recorded across each session as a performance measure of the operant task: autostimulation/normalization (recruitment of sluggish brain cells operating at 7HZ to normalize to a 14HZ posture) of the functioning of the central cortex, resulting in increases in the amplitude levels (energy) of the 14HZ discharge pattern. In addition, ongoing measures of 5, 7, 10, and 12HZ bands of electrocortical activity (energy/brainwaves) were concurrently obtained. Specifically, each of the monitored brainwave energy bands was processed through a separate filter (as previously described) and then passed through an optical isolator and then on to a multiplexor for processing by the computer's data processing program. The portable, Nova Systems "Tansey Ten" EEG biofeedback electroencephalograph used in this study is capable of processing any ten brainwave energy bands desired - while training for activation on any single channel. Each filter is digitally "dialable" to the required bandwidth/frequency for either monitoring and/or processing or reinforcing. 7HZ inhibit circuits are optional.

While EEG biofeedback training was continuous for the client (continuous auditory feedback), data acquisition was undertaken in ten, three-minute intervals, with two second pauses in between. This was performed automatically by the computer program - as was an ongoing visual representation of the EEG activity displayed on a video monitor attached to the computer. On the monitor, five channels of pre-selected EEG brainwave energy/activity - in this case 5HZ, 7HZ, 10HZ, 12HZ, and 14Hz - were displayed. The display is in the form of five proportionally expanding and contracting horizontal bars. Digital readings for each bar's varying Peak-to-Peak microvolt value accompanied each bar, and changed with it. Data acquisition was accomplished across a 30 minute time frame, with an additional ten minutes of further training available to the client depending upon time constraints.

Thus, the monitor displays changes in EEG energy/amplitudes across the five brainwave bands so that the trainer can act on those changes, and give verbal feedback to the client relating to the changing "signature". If the client strays off frequency (daydreaming, actively thinking about tonight's dinner party, etc., with concurrent surges of 7HZ activity, surges of 10HZ activity, etc.), it is immediately seen as a change in the patterns displayed on the video monitor, and the client can be quickly guided back to producing brainwave activity in the desired (14HZ) energy range. At the end of the training session, the computer displays the mean amplitude, high and low readings, and SD across the ten, three-minute, data acquisition intervals.

The average number of sessions for this group was 27.9 . EEG 14Hz biofeedback training sessions were scheduled once weekly. Each session commenced with a 10 to 15 minute review of each youngster's status for the previous week. Instructions during the EEG

biofeedback training sessions were presented to the youngsters while they were in a reclining position with their eyes closed. The instructions were: "Now, let yourself become hollow and heavy. Just let yourself be a hollow, heavy, rock; quiet, hollow, and heavy - and let the beeps come out." Intermittent, positive reinforcement (verbal praise for "beep" production and signature shifting) was provided, such as: "that's very good. The more beeps, the better your brain works. The better your brain works, the better your ability to be calm and learn." In the course of training, if the visual display showed a shifting away from the desired 14Hz posture, the initial orientation instructions were repeated. A contract was made to provide a tangible reward, in the form of a "Matchbox Car", "California Raisin" bookmark, etc., at the end of each EEG biofeedback training session, contingent upon the youngster being trained having "let a lot of beeps come out".

An uncontrolled single group outcome study was conducted. Its' aim was to assess the impact of trained increases of this 14Hz central cortex brainwave rhythm. In search of relations between changes in brainwave activity and learning related, psychometrically valid, samples of behavior, the Wechsler Intelligence Scale for Children - Revised (WISC-R) was chosen as it is the chief psychometric instrument utilized in the assessment of intellectual and learning disabilities evaluations. Due to their frequent use in compiling WISC-R based learning disability profiles, Bannatyne category (Bannatyne, 1971, 1974) and Kaufman factor (Kaufman, 1979) scores were determined for each youngster by summing the scaled scores of the subtests comprising each category and factor. As these youngsters were child study team diagnosed, their pre-treatment WISC-R scores as measured by the child study teams were accepted as baseline. Post-treatment WISC-R scores were ascertained by a variety of testers; myself, the same child study team, and by other practitioners. The identity of the "re-tester" had no observable effect on re-test outcomes. Several of the most dramatic improvements/normalization of IQ levels (with functional improvement and academic attainment sufficient for them to be re-examined and de-classified from a Perceptually Impaired status), came out of child study team re-evaluations, where the testing was conducted in a single-blind condition.

RESULTS

Brainwave Signatures

The changes in this group's brainwave signatures are shown in Figures 1, 2, and 3. (Pub. note -- These graphs are not yet available due to technical web publishing hurdles. It is expected these will be available by 9/95. The three graphs depict the different Hz responses and the differences by IQ band, from pre-training to post-training.)

As a group (Fig. 1), the brainwave signature seemed to normalize and shift about alpha (10Hz); with those brainwave bands below (5Hz and 7Hz) decreasing in monitored energy levels, and those brainwave bands above (12Hz and 14Hz) increasing in monitored energy levels. A repeated measures analysis of variance, at each brainwave band, showed that these changes were not due to chance but reflected significant changes in the monitored brainwave signatures. The energy in the lower brainwave bands as monitored (5Hz and 7hz) diminished by .088% ($F = 5.938$, *df* 1 and 23, $p < .05$) and 16.08% ($F = 11.670$, *df* 1 and 23, $p < .05$) respectively; while the energy in the 10 Hz

band did not change significantly (F = .267, *df* 1 and 23, Nonsignificant) with the 12Hz, and, importantly the 14Hz brainwave bands showed highly significant positive shifts in mean energy by 21.39% (F = 18.575, *df* 1 and 23, $p < .0005$) and 48.95% (F = 64.827, *df* 1 and 23, $p < .0005$) respectively. As observed, the 2.1 times greater amount of energy in the Theta band (7Hz) as compared with the "sensorimotor/SMA" band (14Hz) which characterized the pretreatment learning disabled state of affairs was reduced by 64.3% through this EEG biofeedback regimen.

Figures 2 and 3 depict the brainwave signatures of the group as broken down into subgroups according to Wechsler's (1974) Borderline (Pre-treatment FSIQ 70-79), Low Average (Pre-treatment FSIQ 80-89), Average (Pre-treatment FSIQ 90-109), and High Average (110-119) categories of intellectual function. Statistical analyses of differences between these subgroups were not conducted due to their small sizes. Nevertheless, visual inspection indicates that, for this sample of 24 learning disabled, there is a tendency towards increased 5Hz and 7Hz energy levels as FSIQ decreases.

The Wechsler Intelligence Scale for Children - Revised
Pre and Post-EEG Biofeedback Training Profiles

The mean pre, post, and difference scores, obtained by the subjects on the WISC-R are presented in Table 1. Table 2 presents an overview, of pre and post-WISC-R and EEG biofeedback data, grouped according to pre-treatment FSIQ. Statistical criteria for significance are those provided by Wechsler (1974). 22 of the 24 subjects manifested increases in their Full Scale IQ scores of a least one standard deviation (15 IQ points); with the remaining 2 cases (13 & 24) showing an increase of 14 IQ points and 13 IQ points respectively. Both Verbal and Performance IQ scores increased for all subjects. As a Group, their post-EEG biofeedback training scores, substantially exceeded their pre-EEG biofeedback training scores over and above any expected gains due to a retest factor; i.e. more than 3.5 points increase in VIQ, more than 9.5 points in PIQ, and more than 7 points in FSIQ (Kaufman, 1979). In addition, subjects with either a significant - greater than 12 point - Verbal > Performance IQ anomaly (five cases) or Performance > Verbal IQ anomaly (five cases), exhibited more than twice as much increase in the lower of the two IQ scores; regardless of whether it was the Verbal or Performance measure.

TABLE 1 Group WISC-R Profiles

Pre and Post Mean IQ and Subscale Scores

N = 24	PRE	POST	DIFF	
Verbal Subtests				
Information	9.33	11.20	+1.87	
Similarities	10.54	14.04	+3.50	*
Arithmetic	9.20	11.29	+2.09	
Vocabulary	9.08	11.29	+2.21	
Comprehension	11.16	14.58	+3.42	*
Digit Span	7.62	9.79	+2.17	
Performance Subtests				
Picture Completion	10.54	13.54	+3.00	*
Picture Arrangement	10.58	13.37	+2.79	
Block Design	10.16	11.79	+1.63	
Object Assembly	9.87	13.20	+3.33	*
Coding	7.54	9.95	+2.41	
Verbal IQ	98.79	115.00	+16.21	*
Performance IQ	98.12	117.37	+19.52	*
Full Scale IQ	98.29	118.04	+19.75	*
Scatter Indices				
Verbal IQ Range	56	53	- 3.00	
Performance IQ Range	59	60	+ 1.00	
Full Scale IQ Range	56	59	+ 3.00	
V - P Discrepancy	10.66	7.79	+ 2.36	
Bannatyne Categories				
Spatial	30.58	38.83	+ 8.25	
Verbal Conceptualization	30.79	39.92	+ 9.13	
Sequencing	29.96	31.04	+ 1.08	
Acquired Knowledge	27.62	33.79	+ 6.17	
* Increase equals or exceeds one standard deviation				

TABLE 2 Pre and Post EEG Data Ranked According to Full Scale IQ

		FSIQ	VIQ	PIQ	5Hz	7Hz	10Hz	12Hz	14Hz	AGE	SESSIONS
	Pre-	70	72	72	10.13	12.09	14.57	5.761	3.84	13.66	33
B	Post-	85	86	68	10.77	9.8	9.7	5.222	5.34		
R	Pre-	76	80	74	15.20	19.50	11.10	8.20	6.01	5.25	34
D	Post-	99	98	100	16.50	15.40	11.10	8.20	7.60		
R	Pre-	76	75	81	21.70	18.30	19.90	11.10	6.40	10.66	37
L	Post-	91	88	96	18.38	17.40	17.16	10.80	8.95		
I	Pre-	79	80	81	17.35	12.65	7.46	4.96	4.53	9.83	38
N	Post-	106	108	104	16.88	10.30	6.40	6.73	6.86		
	Pre-	80	81	81	14.50	9.70	8.30	3.40	2.60	12.25	36
L	Post-	96	91	104	14.50	8.80	12.10	7.40	5.90		
O	Pre-	85	79	93	18.70	19.10	10.90	7.0	5.60	7.92	30
W	Post-	103	98	109	16.40	18.60	12.80	11.30	13.0		
	Pre-	88	97	81	6.43	7.54	10.0	5.70	4.68	9.75	35
A	Post-	122	118	121	5.84	6.46	9.20	5.42	6.38		
V	Pre-	89	95	86	20.01	8.40	10.20	5.80	4.60	7.33	34
G	Post-	118	118	114	16.51	3.70	9.50	6.80	6.70		
	Pre-	91	95	92	9.59	10.80	8.86	3.91	4.57	15.50	36
A	Post-	108	103	112	9.97	8.50	5.82	5.26	6.16		
V	Pre-	92	88	100	13.78	13.30	12.23	4.98	4.65	9.75	15
E	Post-	128	125	126	10.90	11.80	15.0	5.80	5.80		
R	Pre-	92	95	92	11.57	10.36	8.20	5.23	4.74	15.50	26
A	Post-	108	103	112	9.80	8.50	9.17	5.42	6.43		
G	Pre-	95	98	92	18.09	17.24	13.44	5.78	5.20	7.67	29
E	Post-	114	119	105	16.80	13.86	13.70	5.90	5.90		
	Pre-	101	109	91	7.80	9.23	9.14	4.73	4.08	14.0	26
A	Post-	114	113	112	6.70	7.16	14.67	7.37	6.52		
V	Pre-	101	92	111	19.40	18.01	8.03	4.84	4.50	10.0	27
E	Post-	122	109	131	15.50	10.80	9.40	5.40	5.90		
R	Pre-	102	112	91	14.30	17.90	8.0	4.20	3.40	10.16	25
A	Post-	123	125	115	17.90	20.50	8.70	7.90	7.50		
G	Pre-	104	101	108	21.70	29.18	9.34	5.15	4.30	9.75	26
E	Post-	118	111	123	20.32	16.35	9.39	6.60	6.59		
	Pre-	109	109	108	15.10	10.50	8.10	5.20	3.60	9.08	39
H	Post-	126	127	120	16.60	12.04	7.75	8.05	6.63		
I	Pre-	112	114	108	16.90	16.30	10.80	5.20	4.60	8.08	23
G	Post-	127	125	123	7.82	9.28	9.99	6.42	6.07		
H	Pre-	112	122	98	12.90	13.60	9.25	7.21	5.43	11.91	32
	Post-	133	136	123	13.20	16.10	10.75	8.11	7.80		
A	Pre-	114	107	120	8.50	11.10	10.70	5.26	4.60	10.16	18
V	Post-	130	125	129	8.40	8.30	7.80	6.70	6.57		
G	Pre-	116	100	131	11.90	12.02	7.20	6.80	4.20	11.83	25
	Post-	136	125	138	11.80	11.80	24.13	7.18	5.80		
S	Pre-	124	117	128	10.30	10.90	10.60	5.0	4.40	7.75	15
U	Post-	144	133	146	10.40	9.80	11.40	5.80	6.20		
P	Pre-	125	128	115	11.56	12.86	12.06	5.32	4.62	13.41	13
E	Post-	141	137	135	7.90	11.10	8.90	5.80	5.90		
R	Pre-	126	125	121	12.0	11.20	11.60	4.60	4.20	10.08	18
	Post-	141	139	133	9.50	9.40	9.10	4.80	6.60		

Bannatyne's and Kaufman's Categories

This sample of 24 had 37.5% of them manifest pre-treatment Bannatyne patterns of Spatial > Verbal Conceptualization > Sequential categories. Of these 9 cases, 8 out of 9 had pre-EEG biofeedback treatment FSIQ's within the Low-Average to High-Average ranges of intellectual function. One case fell within the Borderline range with a pre-treatment FSIQ of 76. Post-treatment inspection showed that 7 out of the 9 cases of classic Bannatyne patterns, long associated with genetic dyslexia and a wide variety of learning disorders, retained that pattern while shedding the learning disorder. Kaufman's Verbal Comprehension and Perceptual Organization factors reacted in a similar fashion; with a 11.0 and a 11.25 mean increase respectively.

DISCUSSION

Recent research on the Wechsler scales have demonstrated them to be valid and reliable measures of intellectual status for normal and learning disabled populations (Anderson, Kaufman & Kaufman, 1976; Kaufman, 1981; Schiff, Kaufman & Kaufman,1981), and to yield up ***stable*** Verbal, Performance, and Full Scale IQ scores for a variety of groups of learning disabled. Thus we find stable IQ scores on retest ***7 months later*** for a group of 161 of learning disabled (Smith, 1978), ***3 years later*** for a group of 382 handicapped children from three racial/ethnic groups (Elliott, Piersel, Witt, Argulewicz, Gutkin, and Galvin, 1985), ***15 years later*** for a group of 133 learning disabled (Sarazin & Spreen, 1986), and ***17 years later*** for a group of 11 learning disabled (Frauenheim & Heckerl, 1983). However, these findings consistently show little impact by many years of remedial education and/or psychotherapeutic intervention on the functional status of the learning disabled.

The results of this study verify and extend previous findings with application of this EEG biofeedback regimen (Tansey, 1982; Tansey & Bruner, 1983; Tansey, 1984, 1985, 1986, 1990). Specifically, a normalization of brain function was observed wherein slow wave activity (7Hz) decreased in overall energy concomitant with increases in energy of 14Hz central cortical brainwave activity. For this sample of 24 learning disabled youngsters, the most significant changes in their WISC-R subtest scores indicate that their greatest functional growth (post-treatment change >3 scale score average increase) was clustered about those areas tapped by four specific subtests: Comprehension (on average a 3.416 scale score increase and a 30.59% numeric increase), Similarities (on the average a 3.5 scale score increase and a 33.20% numeric increase), Object Assembly (on average a 3.33 scale score increase and a 33.70% numeric increase), and Picture Completion (on average a 3.0 scale score increase and a 28.45% numeric increase). In other words, the increased activation of the central cortical area was associated with increases in bi-hemispheric skills prerequisite to a successful learning posture and acquisition of the mechanics of reading: i.e. right brain perceptual/attentional readiness (Object Assembly), in increased visual attention to the environment and utilization of learning sets (Picture Completion), and in skills necessary to the functional usage of "learning experiences" as building blocks for further development - such as greater usage of abstract and logical

modes of thinking and reasoning (Similarities), and functional synthesis of past experience/memory/understanding in the evaluation of everyday life (Comprehension).

The Bannatyne pattern of WISC-R subscales is well documented as being consistently associated with diagnoses of learning disabilities (Clarizo & Bernard, 1981; Gutkin, 1979; Henry & Whittman, 1981; Raviv, Margalith, Raviv & Sade, 1981; Schiff, Kaufman & Kaufman, 1981; Smith, Coleman, Dokecki & Davis, 1977; Volkoff, 1985), and reading impairment (Decker & Corley, 1984; Rugel, 1974). The predictive value and clinical utility of the Bannatyne pattern has also been noted to be possibly influenced by FSIQ levels - with its applicability limited to subgroups of learning disabled with low-average to above-average FSIQ levels (Fisher, Wenck, Shurr & Ellen, 1985; Smith, Coleman, Dokecki & Davis, 1977; Volkoff, 1985). The results of this study also show Bannatyne's classic pattern to be representative of learning disabled with pretreatment FSIQ scores within the low-average to high-average intellectual ranges. But, when the FSIQ levels increased, after EEG biofeedback training, by a standard deviation, then the classic Bannatyne pattern seemed to merely reflect a functional brain posture rather than a brain based learning impairment.

Robinson (1989, p.209) echoes the author in his affirmation that "the study of human intelligence must ultimately involve the study of brain processes". Robinson's posits a neurological basis for variations in intelligence wherein the relative balance of thalamocortical arousability determines the natural frequency of free or 'spontaneous' oscillations in the thalamocortical 'circuits' which determine the signal characteristics of the EEG power spectrum at any given point. According to Robinson's theory, the energy reduction/changes in Figure 1 would necessitate increased IQ scores. This would be the case because the EEG biofeedback procedure activated an increase in neural excitation and a positive shift in natural frequency (and overall arousability) towards an optimal level wherein the realization of higher IQ would be necessary. In this, the active promotion of a balance between neural excitation (natural frequencies above 10Hz) and neural inhibition (natural frequencies below 10Hz) - which is consistent with a state of middling arousability which coincides with high IQ.- is crucial to the acquisition of higher order learning and high scores on measures of cerebral efficacy/intelligence. In the case of pre-treatment low IQ learning disabled children, Robinson's theory would predict low arousability/neural inhibition with initial natural frequencies weighted below 10Hz. This is indeed the case with my data. His theory would also predict that the highest IQ's would be associated with greater energy in the 10Hz band and increased thalamocortical balance. My findings (Figures 2 and 3) again support his. In sum, my procedure, when viewed from Robinson's theory, yields increases in IQ because it positively corrects pathological cerebral dysfunction. According to Robinson, the brain activation posture achieved via my EEG biofeedback training regimen is only reflected in higher IQ levels. My data agrees with his hypothesis in that the resultant brain state is only reflected in higher IQ levels for the recipients of this EEG biofeedback regimen with remission of learning disability.

Frequently, in change producing procedures, the question arises as to whether one is dealing with a causal Vs a functional impetus for observed change. In this case, the

question of a "functional link" between EEG amplitudes and IQ increases would be of interest to some; i.e. does the procedure promote synergistic normalization of cerebral function by "revving up" the engine, or does production of significantly increased amplitudes of the 14Hz brainwave band bear a direct relation/correlation to significant increases in Verbal, Performance and Full Scale IQ measures? In performing Pearson product-moment correlations between all EEG bands monitored and FSIQ, PIQ, and VIQ scores, I did not obtain any correlations higher than a 0.359 (This highest correlation which was found between 5Hz and FSIQ shows that 12.8% of the variance in 5Hz activity was associated with the variance of FSIQ changes). Thus, the promotion of a synergistic normalization of cerebral function by "revving up" the engine seems to be an acceptable candidate as the functional impetus for observed change. In this context, the central nervous system may be viewed as a matrix of functionally interrelated cerebro-cortico-neural networks with the ability for any pattern of neural activation, irrespective of its locus of origin, to effect an alteration in the entire matrix. As such, localized areas of functional specialization may be viewed as subnetworks enmeshed in the larger matrix; whose "signature" of neural discharge parameters are but a part of the greater symphony of brainwave rhythms reflective of the functioning neuroanatomy of the global matrix. Robinson's corroboration of my findings supports the view that, we will not find the correlation of any one wave band to be directly related to higher IQ, but rather the shifting of the EEG spectrum (suggestive of a functional reorganization of cerebral activation) as reflecting the neurologic substrate requiring improved function. The operative link is the usage of increased 14Hz production from the SMA as a catalyst to initiate a synergistically efficacious brain based normalization in the pathologic pre-treatment balance of cerebral inhibition and excitation.

The present study is based on a limited sampling (N=24) of a very motivated, pay-for-service, private practice, population. The lack of a control group is a limitation vis-à-vis classical experimental design, and in the absolute inferences to be drawn about the experimental effects. This is why a separate, concurrent, psychometrically valid and stable over time, measure of meaningful behavior (WISC-R) was used to serve the discriminant function in verifying the efficacy of the physiologic changes fostered by this EEG biofeedback regimen. It is hoped that this paper will serve as a useful pilot for further studies with larger samples and encourage further utilization of EEG biofeedback training as an effective clinical (***private practice***) tool for the treatment of learning disabilities and CNS dysfunction.

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