

EEG Biofeedback Training for Attention Deficit Disorder, Specific Learning Disabilities, and Associated Conduct Problems

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►ABSTRACT

The efficacy of brain wave training and EEG biofeedback in the remediation of attentional deficits and specific learning disabilities is evaluated for a study population of fifteen school-age children in a clinical setting using psychological and academic testing. The Wechsler Intelligence Scale for Children--Revised (WISC-R) is used in combination with the Wide Range Achievement Test (WRAT), Peabody Picture Vocabulary Test (PPVT), the Tapping Subtest of the Harris Tests of Lateral Dominance, and the Benton Visual Retention Test (VRT). Behavioral changes are assessed by means of teacher and parental reporting. The training protocol is enhancement of EEG activity in the 15-18 Hz regime, with suppression of excessive activity in the 4-7 Hz and 22-30 Hz regions. Significant improvements in cognitive skills, academic performance, and behavior are found, and confirmed in follow-up. Average improvement in WISC-R full-scale IQ was 23 points. A preference for 15-18 Hz training versus 12-15 Hz training is indicated.

►INTRODUCTION

A number of studies evaluating EEG biofeedback for hyperactivity, attention deficit disorder (ADD), and learning disabilities have already yielded evidence of improvement in cognitive skills and academic performance. (Shouse, 1979; Lubar, 1984; Tansey, 1990). The focus initially was on remediation of hyperactivity in cases which were responsive to stimulant medication, and hence were thought to be most obviously traceable to cortical underarousal (Lubar, 1976). This work was grounded on earlier success of EEG augmentation training in the 12-15 Hz region with epileptic seizures of predominantly motor symptomatology (Serman, 1972). Such augmentation training was then combined with inhibition of excessive activity in the 4-7 Hz region (Serman, 1974). Viewing hyperactivity as motor disinhibition motivated use of the same protocol.

The 12-15 Hz region was identified by Serman as associated with specific rhythmic activity (referred to as sensorimotor rhythm, or SMR) which governs the setpoint, or the poise, of the motor system (Serman, 1982a). Subsequently, it was found that cases of attention deficit disorder without hyperactivity (as defined in the DSM III) were also responsive to the training, and that cognitive deficits associated with attentional deficits could be effectively remediated with both 15-18 Hz training (Lubar, 1984) and with 12-15 Hz training (Tansey, 1990). The more universal applicability of the technique meant that a more generalized model was needed, and the efficacy of both 15-18 Hz and 12-15 Hz training also called into question any simple identification of the mechanism with the SMR rhythm. No comparable rhythm has been identified in the 15-18 Hz regime, which is referred to as "beta" in the following.

The present work is motivated by the need to confirm the previous studies, and to quantify and particularize the benefits in terms of cognitive function and short-term memory which may be attributable to the training. There were differences in protocol, in electrode placement, in instrumentation, and in the role of the biofeedback therapist in the

prior studies. This variety in approach also calls for additional studies which may allow discernment of the preferred protocol. Finally, there has been sufficient anecdotal evidence of a more generalized efficacy of the present EEG training protocol, e.g. for behavioral problems, that a more inclusive model may be required to explain all of the findings.

The previous work supports the hypothesis that deficits in cortical activation and control are observable in the statistics of cortical neuronal activity, as reflected in EEG spectral density distributions and in time domain phenomena such as spikes, other characteristic waveforms, and paroxysmal activity. It is therefore proposed that EEG biofeedback training in general, and beta and SMR training in particular, may effect cortical regulation in a very broad sense when it is used to train the EEG toward more state-appropriate frequency distributions. This is accomplished by impacting on those mechanisms, originating in the reticular formation of the brain stem and mediated by the thalamus and the hypothalamus, which govern states of arousal and level of consciousness, including cortical activation. The mode of generating SMR or other rhythmic brain wave activity via the stimulation of a thalamic gating mechanism was first described by Serman (1982).

Specifically, the presence of high-amplitude, low-frequency activity is inappropriate for a state of attentive arousal under which the training takes place. Similarly, low amplitude in the beta region appears to be associated with cortical underarousal (Lubar, 1989). Conversely, excessive high frequency activity may be observed in children showing anxiety symptoms (our own observation). Such waveforms yield high amplitude in the upper beta band of 22-30 Hz. The training protocol, in terms of reward and inhibit bands, follows directly from these observations. Extraneous factors impinge as well: head and neck muscle activity intrudes into the beta band, allowing clients to obtain rewards inappropriately, unless such activity is specifically inhibited.

■ EXPERIMENTAL METHOD

Given our operating hypothesis of a general applicability of the technique of beta/SMR training, it was appropriate to give the present work a broad, inclusive cast, as opposed to a narrow focus. The constraints of a clinical setting in terms of availability of subjects also militate against a narrow focus. Children of ages 6 to 16 were accepted into the study if they were referred for academic problems, attentional deficits, hyperactivity, or conduct problems. Eighteen children were accepted into the study. Of these, three only received about six training sessions and terminated the training for personal reasons which did not relate to consequences of the training. The results of the remaining fifteen are presented in the following.

The training protocol employed 15-18 Hz augmentation training, with concurrent inhibition of excessive 4-7 Hz and 22-30 Hz amplitudes. The present work may therefore be considered as a study in beta training, for comparison with Tansey's 14-Hz reinforcement, and with Lubar's use of a similar protocol with different electrode placement.

Electrode placement in the present study was bipolar, at sensorimotor cortex, along the Rolandic fissure. Placement was C1-C5, or C2-C6, per the International 10-20 system. An ear ground electrode on the same side being trained was also used. Training was performed on the dominant hemisphere, unless there were hemispheric differences in the EEG, in which case the side showing the larger or more deviant EEG was trained. Verbal reporting from the client, family, and teachers was used to adjust the training protocol throughout. By way of comparison, Lubar employs a frontal-temporal placement, whereas Tansey uses a large-area electrode at Cz in a monopolar configuration with an ear reference and ear ground. Our choice of electrode placement was largely historically rooted in the early work of Serman and Lubar.

Instrumentation was by Neurocybernetics. A two-channel EEG amplifier from Mendocino Microcomputers was used. The signal was digitally processed in a PC. The primary EEG trace and the three filtered waveforms are continuously displayed to the therapist in a scrolling or chart recorder type of display. This information is used by the therapist to provide guidance, coaching, and motivation to the client, and helps the client to begin to associate certain mental states with what is observed in the EEG and in the feedback display. The feedback signal is derived digitally in the PC, and is presented to the client via a second computer, which displays a video game in which the brightness and speed of a pacman-like object is governed by the beta amplitude relative to a pre-set threshold. If the theta or high-beta (i.e., 22-30 Hz) thresholds are exceeded, the object goes dark and stops. Binary auditory feedback is provided as well.

The training proceeded in sessions of thirty minutes on the instrument (45-minute contact hour), after an initial intake session of an hour and a half, in which the history was taken, baseline EEG records were obtained for both hemispheres, and a training session was conducted. The academic testing was accomplished in a two to three-hour session on another day. At each training session, the last six-minute segment of the EEG record was stored on the client disc, along with an updated history of thresholds and other performance data from every session. A chart recorder output of representative EEG data was also obtained at each training session.

Academic and cognitive skills testing encompassed the full WISC-R, the PPVT, the WRAT, Benton VRT, and the Tapping Sub test of the Harris Tests of Lateral Dominance. The selection was made partly on the basis of the broad familiarity with these tests among educators, psychologists, and educational therapists, who will serve as the primary referral source for this type of training in the foreseeable future.

The subject population had the following characteristics: Of the fifteen subjects, fourteen had been diagnosed as having attention deficit disorder. Of these, seven had prominent symptoms of hyperactivity, and of these, two were on medication for the condition. Seven subjects were identified as having specific learning disabilities; of these, four were identified with dyslexia. Six of the subjects were characterized by oppositional/defiant disorder, and two by conduct disorder. Five of the children reported chronic headaches. And thirteen of the group reported various sleep disorders, including two cases of sleep anxiety (inability to fall asleep in one's own bed or room), four cases of sleep walking

and sleep talking, and three cases of nocturnal enuresis. Mood disorders were common as well, with three cases of chronic anxiety, and four of childhood depression or dysthymia. One subject exhibited obvious motor tics.

Training was conducted for an average of 35 sessions, at a rate of 2-3 sessions per week. One subject was in ongoing educational therapy and two were in ongoing psychotherapy.

RESULTS

WISC-R Subtest Data.

The data to be presented in the following will cover the test results for the entire study population. Space does not allow review of individual case histories, nor of the EEG phenomenology characterizing this population. The average of the WISC-R scores for the study group is shown in Figure 1. It should be noted that the pre-test scores were largely above age-corrected norms (10 on the scale), demonstrating the generally high mental competence of members of the group. Moreover, the average data exhibit minimums for the four subtests of the WISC most closely associated with attentional deficits, namely Arithmetic, Coding, Information and Digit Span (the "ACID" test). Noteworthy increases are observed for each subtest of the WISC. The statistical significance of the results will be addressed below.

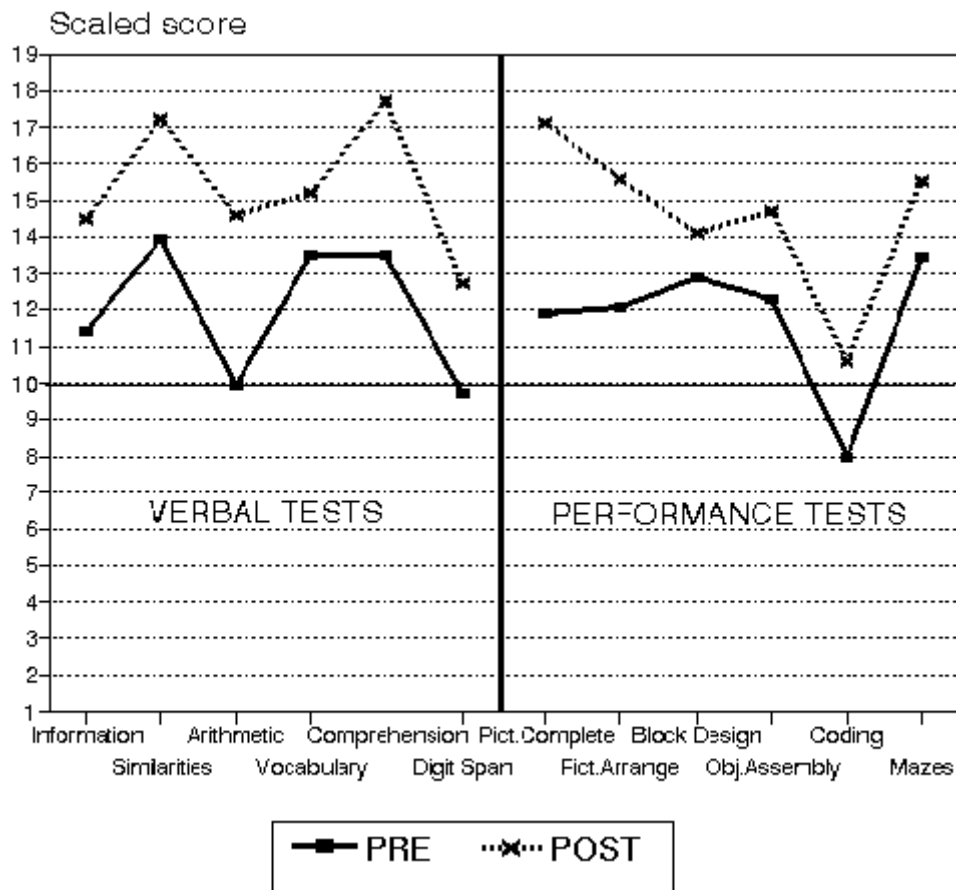


Figure 1. Average results of WISC-R testing for study group of fifteen, comparing pre- and post-EEG training.

The average increases in the WISC-R subtests are shown in Figure 2. Here only those data are considered in which the pre-test score was less than 18 or 19, because the small amount of improvement possible in these cases would skew the data, and because such high pre-scores are in any case not illustrative of attentional deficits or specific learning disabilities. The subtests have been rank-ordered by the amount of the average increase observed. Interestingly, three of the subtests associated with attentional deficits showed very comparable changes: Digit Span (3.2), Coding (2.6), and Information (2.6). The Arithmetic subtest showed much greater improvement (4.7).

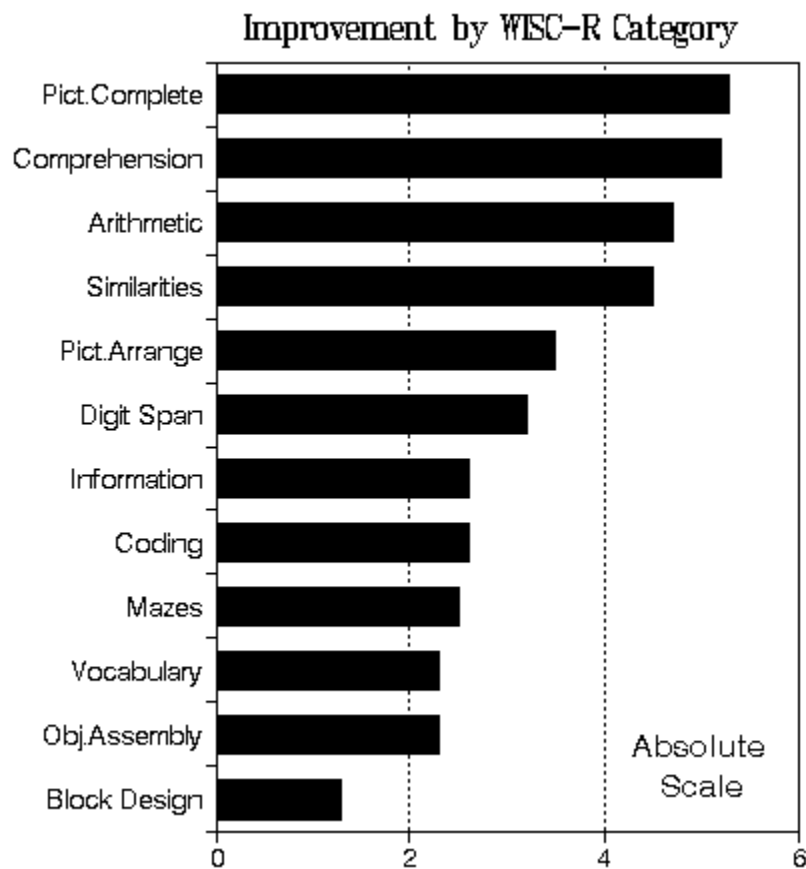


Figure 2. Average increases in WISC-R subtest scores for entire group. Pre-scores of 18 and 19 were left out of calculation. Subtests are rank-ordered by the amount of increase observed.

The overall averages given above obscure the dependence on WISC pre-test scores. It is found that the largest improvements occur in those areas which are in most significant deficit. To illustrate this, the data for all subtests with initial values of less than ten are shown in Figure 3. The number of data points comprising each bar is also indicated. The

average changes are four units or greater for all subtests except for Mazes and Block Design. Moreover, the ACID test categories are tightly distributed, with gains ranging from 4 units to 5. The average gain for all the data of Figure 3 is 5.1 units.

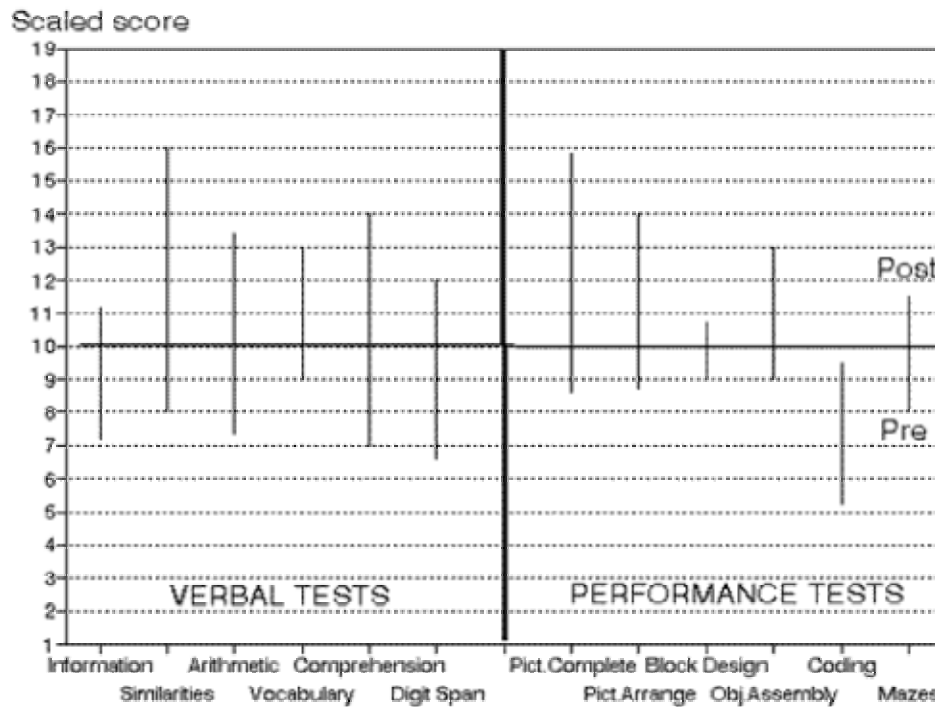


Figure 3. Average pre-post WISC-R data for all subtest scores in which the pre-test value was less than 10. The number of data points comprising each average is shown.

It is useful also to assess the significance of the data with pre-test scores of less than ten. There are 48 such data points. If, for example the reproducibility of subtest data is taken to be 1.5 units, then there is 97% confidence that three units represents a real change. Even if the reproducibility is assumed to be only 2 units, a 3 unit change may be taken to be significant with more than 80% confidence. Out of the 48 candidate data points, 42 showed changes of three units or more (88%). The distribution in terms of subtests is given in Table 1. Nine of ten subtests show improvements which meet this criterion of significance. The exception is Block Design. All the subtests where deficits are found in at least 30 percent of the study group (Information, Arithmetic, Digit Span, Picture Completion, and Coding) showed highly significant changes.

Table 1. For all subtests of the WISC-R, and for all cases in which the initial score was less than 10, the number of data points are indicated in which a change of at least three units was observed.

WISC-R Subtest	No. of Significant Gains
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(3 or more units)	
Information	5 of 5
Similarities	3 of 3
Arithmetic	8 of 8
Vocabulary	1 of 1
Comprehension	1 of 1
Digit Span	5 of 5
Picture Completion	5 of 5
Picture Arrangement	4 of 4
Block Design	0 of 3
Object Assembly	3 of 3
Coding	6 of 8
Mazes	2 of 2

Table 2 shows the three largest increases observed in scores for each subtest. Highly significant increases are observed for every subtest. The largest gains are in fact outside of the range of common experience for other modalities of treating attentional deficits and specific learning disabilities. On seven of the twelve subtests, gains of seven or more units were observed in at least one case.

Table 2

Three largest gains observed in test population for each WISC-R subtest.

WISC-R Subtest	Three Largest Gains Observed
Information	5, 4, 4
Similarities	9, 8, 7
Arithmetic	8, 7, 6
Vocabulary	6, 4, 3
Comprehension	8, 7, 7
Digit Span	7, 7, 7
Picture Completion	10, 7, 7
Picture Arrangement	8, 7, 6
Block Design	5, 4, 3

Object Assembly	6, 5, 4
Coding	7, 6, 4
Mazes	6, 4, 4

It is also of interest to look at those cases in which all four ACID test scores are below norms. Four subjects satisfy this criterion. The average WISC-R results are shown for this subgroup in Figure 4. The individual subtest scores are shown in Figure 5, to indicate the dispersion in the data. With respect to the ACID test categories, we observe a very tight distribution for Information, Arithmetic, and Coding, with a somewhat greater dispersion for Digit Span. Block Design and Object Assembly are also tightly distributed. The observation of a relatively tight distribution for three of the ACID test categories is corroborative of a common mechanism underlying the deficits.

Figure 4

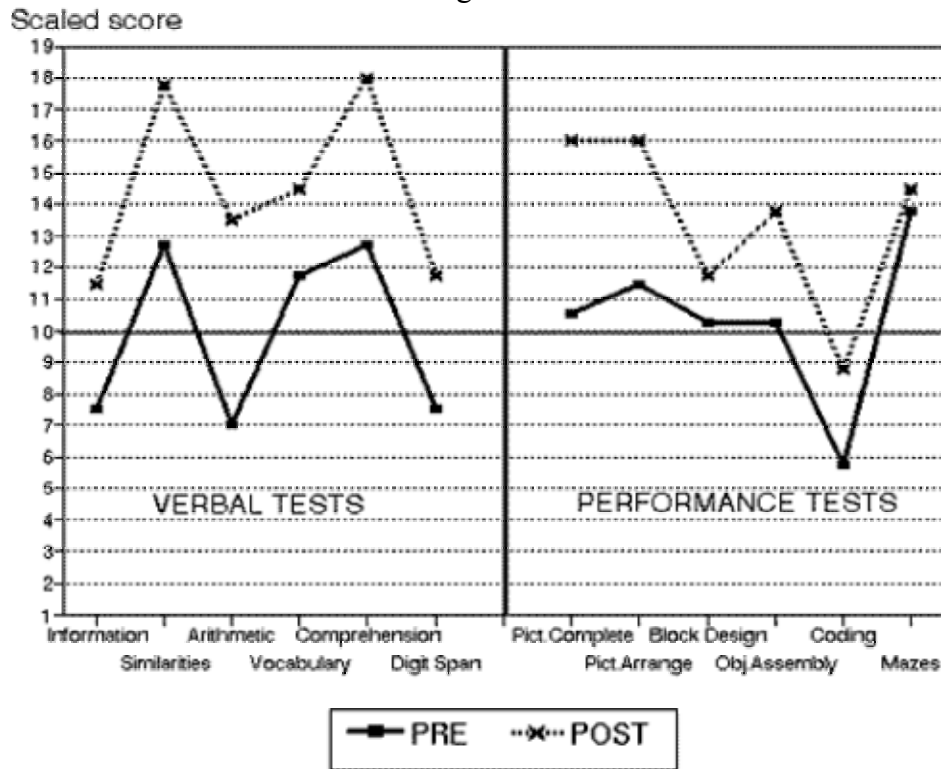


Figure 4. Average WISC-R profiles for the four subjects for whom all ACID test categories were initially below norms.

Figure 5

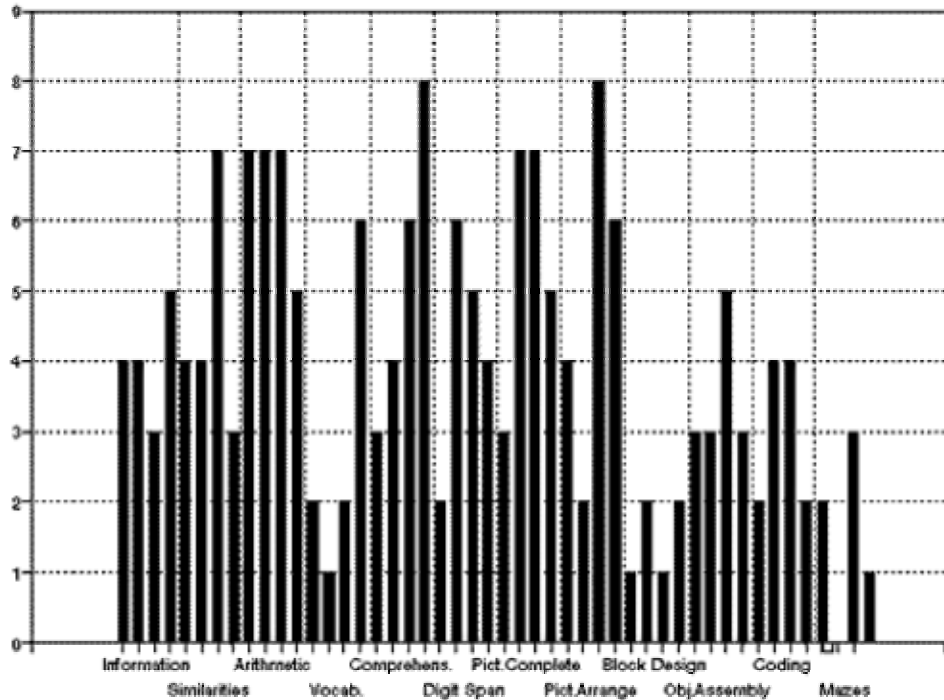


Figure 5. WISC-R subtest score improvements for the four subjects of Figure 4. Observe relatively low dispersion in the data for Information, Arithmetic, Block Design, Object Assembly, and Coding.

WISC-R Verbal, Performance, and Full-Scale IQs

IQ values can be derived from the WISC-R data, from the Verbal and Performance subtasks, and for the combined data set (full-scale IQ). The change in the verbal and performance IQs are shown in Figure 6 for the study population. Most of the subjects showed comparable gains for both verbal and performance IQs. The full-scale IQ changes are given in Table 3 in the order of pre-test IQ. The average IQ increase was 23.5 points. For those individuals whose initial IQ was less than 100, the average gain was 33 points.

Peabody Picture Vocabulary Test

The PPVT was used to augment the WISC-R, since vocabulary is perhaps the best single predictor of IQ. The PPVT evaluates verbal performance without involving word recall. A comparison of the PPVT with the WISC-R in terms of IQ is shown in Figure 7. The results are unfortunately hampered by the age limitations of the two tests, namely 18 in the case of the PPVT and 16.8 years in the case of the WISC-R. Whereas the results show consistent trends in some of the cases, others in fact show decreases in PPVT scores in the retest. We can offer no ready explanation for the divergence in the two tests. Further investigation would be appropriate.

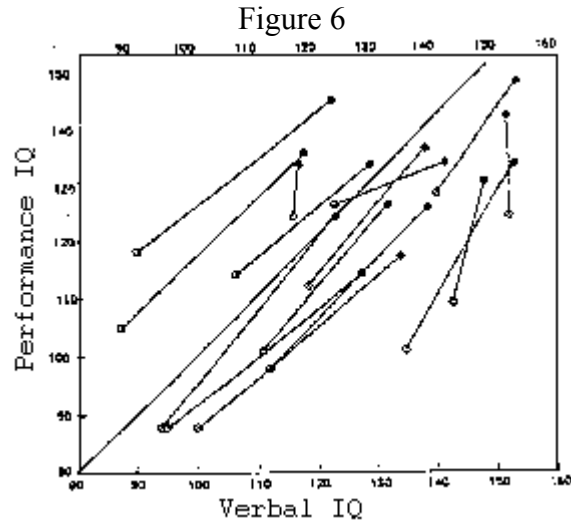


Figure 6. Verbal and Performance IQs derived from WISC-R data are shown pre- and post-training for the study population. In most cases, the changes are comparable in both verbal and spatial ability.

Table 3.

Full-scale WISC-R IQ changes listed in the order of initial value of measured IQ.

Full-scale WISC-R IQ changes.

Initial Full-Scale IQ	Measured Change
90	+37
91	+33
96	+34
99	+29
103	+35
105	+29
106	+27
111	+24
118	+24
123	+5
126	+22
128	+14
130	+14
139	+19
143	+7
Average: 114	+23.5

Figure 7

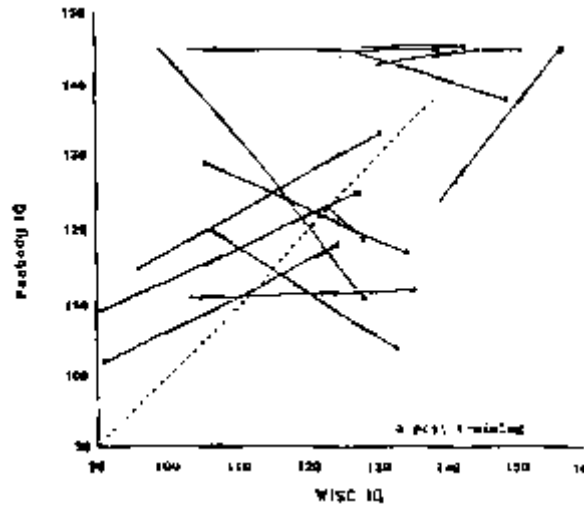


Figure 7.

Comparison of changes in the PPVT and WISC-R IQs. A lack of correlation is indicated for the population as a whole, and a number of Peabody IQ scores actually decreased.

Wide Range Achievement Test

Ten of the subjects also were given the reading and arithmetic subtests of the WRAT. The results are shown in Figure 8 in terms of changes in reading grade level. As in the case of the PPVT, the results were mixed. Six subjects showed major gains in reading performance, but five of these were reading above grade level at the outset of training. Of the three who were in significant deficit in reading, only one showed gains well in excess of chronological age. On the other hand, significant reading improvements were shown by two of the four individuals referred for dyslexia.

The results of the arithmetic subtest of the WRAT are presented in Figure 9.

Improvements in grade level by more than two were shown by four of the ten subjects tested. These had all been in deficit at the outset. On the other hand, two subjects showed significant decreases in score, and one of these had been in deficit. This subject had been in a home-schooling situation, where arithmetic skills may not have been cultivated. The average improvement in grade level for the group was 1.35.

Figure 8.

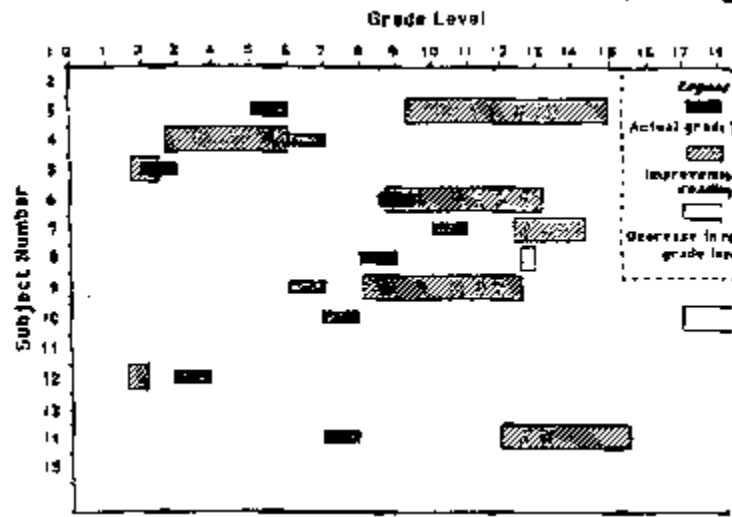


Figure 8. Changes in reading grade level derived from the WRAT are shown for ten of the fifteen subjects.

Figure 9.

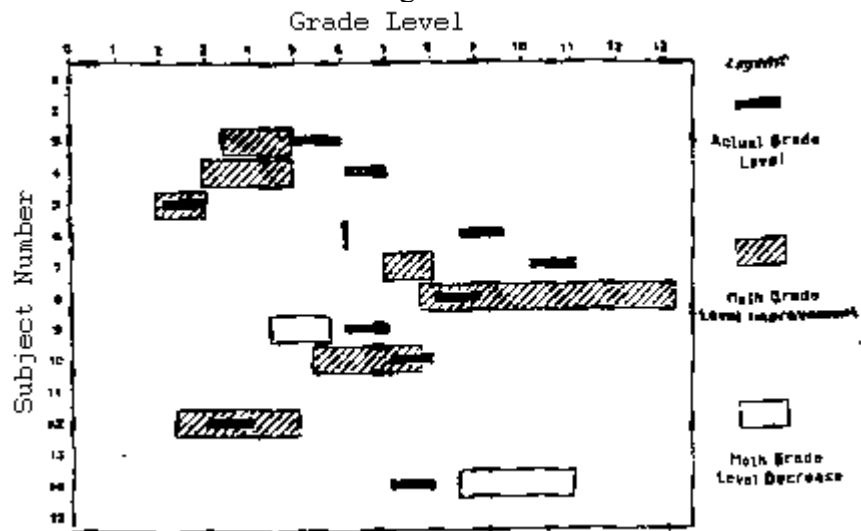


Figure 9. Changes in arithmetic grade level derived from the WRAT for ten of the fifteen subjects. Five of the ten showed significant changes, and four of these were in deficit at the outset.

► Benton Visual Retention Test

Results for the Benton VRT are shown in Figure 10. In this test, simple geometric figures are drawn from memory after a brief exposure. The number of errors made is shown, along with the number of correct representations. The improvements registered in this test are quite striking. Six of the fourteen subjects improved from a rating of average or below to superior. Six showed lesser gains, and two were rated superior already in the pretest, and did not undergo significant change. The test yields unambiguous evidence that the EEG training can improve short-term visual memory. Combined with the significant gains observed on the WISC digit span test of auditory memory, these test results imply a beneficial effect of EEG training on the mechanisms of short-term memory. Benton Visual Retention Test Results for the Benton VRT are shown in Figure 10. In this test, simple geometric figures are drawn from memory after a brief exposure. The number of errors made is shown, along with the number of correct representations. The improvements registered in this test are quite striking. Six of the fourteen subjects improved from a rating of average or below to superior. Six showed lesser gains, and two were rated superior already in the pretest, and did not undergo significant change. The test yields unambiguous evidence that the EEG training can improve short-term visual memory. Combined with the significant gains observed on the WISC digit span test of auditory memory, these test results imply a beneficial effect of EEG training on the mechanisms of short-term memory.

► Harris Tests of Lateral Dominance--Tapping Subtest

The Tapping Subtest was used to determine shifts in handedness, and as a test of changes in eye-hand coordination. The test compares right and left hand performance in a timed challenge in which pencil dots must be placed in rows of boxes. Dominance is defined as right or left if the scores differ by 20 % or more. (To remain close to the data, we will refer to handedness, rather than cortical dominance) Seven of the fifteen subjects significantly improved their score, three by more than 100%. Of the 28 data points in the test (only 14 subjects were given the tapping test), 25 showed an increase. The three decreases were related to left-hand performance, and resulted in these subjects shifting from mixed to right- handedness. The average increase in score was 40%, heavily weighted by the three individuals who underwent very large changes. The median improvement was 20%.

Figure 10

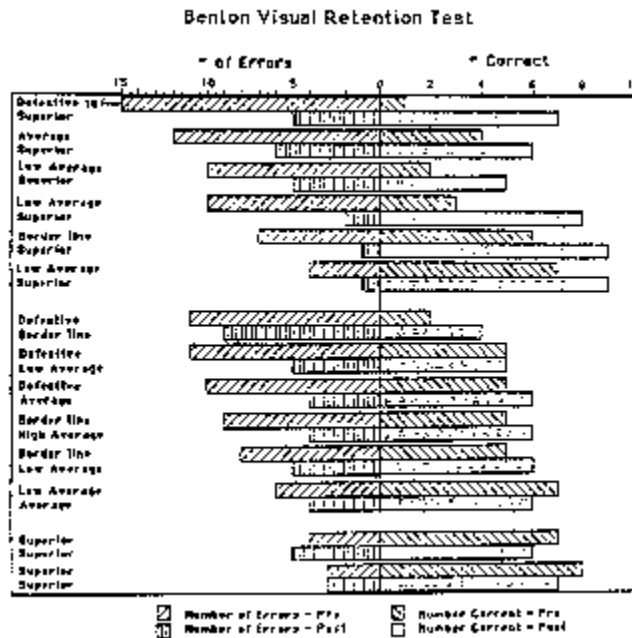


Figure 10.

Results of the Benton VRT are shown in terms of both the number of errors (to the left) and number of items correct (to the right) both before and after training, for fourteen of the fifteen subjects.

The changes in right/left ratio are illustrated in Figure 11. A depletion in the distribution is observed in the mixed-dominance region around unity ratio. The distribution also tightens up for right-handers, and a peak is seen for what may be either intrinsic left-handers or ones where the deficit has not been remediated. The median ratio was found to be 1.20 before training, and 1.30 after. Six of the 14 individuals who did not meet the criterion for right-hand dominance before training met the criterion after training. This is a highly significant finding, indicating an influence of the training on hemispheric organization.

The tendency of the training to enhance right handedness may be explained on the theory that most individuals, perhaps as many as 95% (Hepper, 1990), are intrinsically right-handed, and that injury such as birth trauma leads to compensations in terms of mixed dominance or left-handedness. Birth trauma affects each hemisphere with equal probability. The net effect, then, is a shift toward left handedness. As this deficit in cortical organization is remediated, the "native" right handedness may be restored.

Figure 11

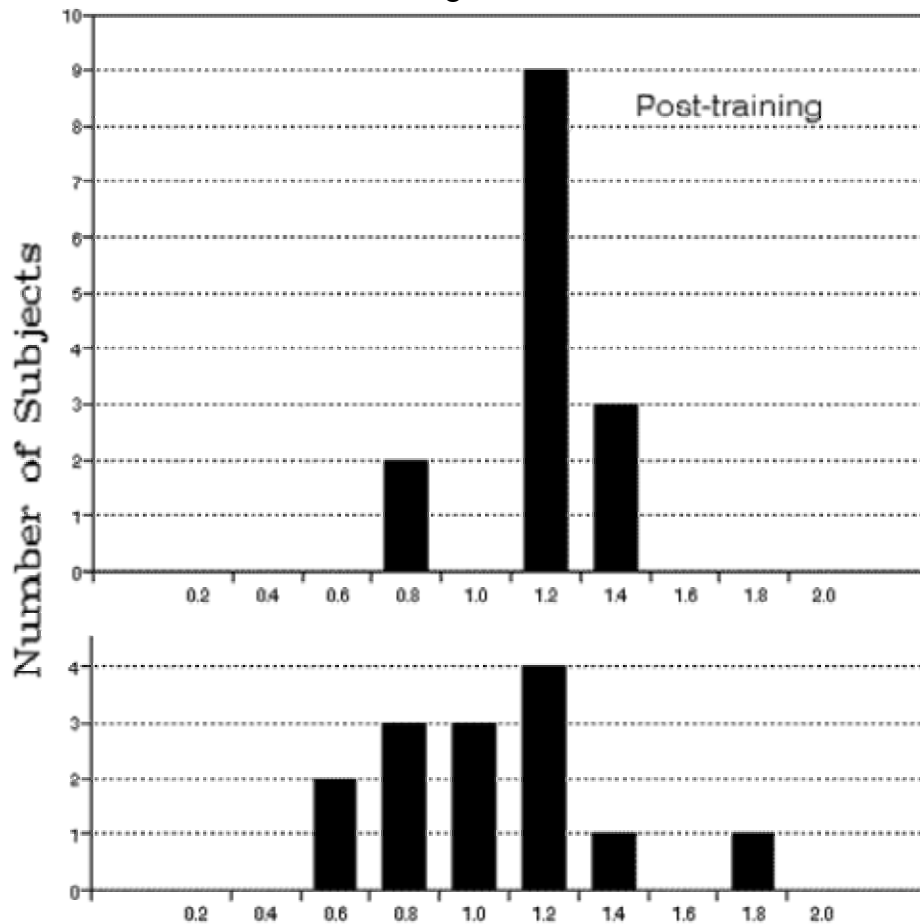


Figure 11. Results of the Tapping Subtest of the Harris Tests of Lateral Dominance, in terms of the ratio of right and left-hand performance both before and after training.

► Follow-up

Follow-up was conducted with parents more than one year after the initiation of EEG training for the study. Questions were asked with respect to a number of categories. Results were scored +1 in case of significant improvement; a score of +2 was given for "major" improvement; and a negative score of one was given for residual problem areas. Sometimes both positive and negative scores were appropriate. The results are shown graphically in Figure 12, where the categories were divided into two groups. In the first grouping are those categories where either significant benefit was seen or few residual problems remain. In the second grouping, we placed those categories where problems remain.

The first category includes those areas in which improvement was expected, such as hyperactivity, concentration, and sleep disorders, and some surprises, such as headache

syndromes. Ranked first was self-esteem. It was quite evident that the children benefited in terms of self-esteem from the fact that the EEG biofeedback training was something they did for themselves. They unambiguously related their progress to their own effort. However, the dominant influence on self-esteem was clearly the objective fact that they were now more functional, their sibling and peer relationships were improved, and their interactions with authority figures, parents and teachers, were better. The category of school grades was affected by the fact that four of the subjects were in ungraded environments. Significantly, grades remained a problem with only one child. The three cases of nocturnal enuresis responded to the training, as did the single case of obvious motor tics.

The second category includes some of the behavioral categories, as well as areas of academic performance. First of all, we note with satisfaction that a lasting impact of the training on behavioral disorders is indicated. On the other hand, significant problems remain. We ascribe this to four factors. First, it is unlikely that the typical 30-40 training sessions are sufficient to deal with behavioral disorders, although they appear to be sufficient to remediate cognitive deficits. Second, a higher standard is undoubtedly applied by parents: whereas they may be pleased that the child is now reading better, when it comes to temper tantrums, success means their complete elimination, not a 70% improvement in incidence. Third, parental expectations tend to ratchet up with improvements in the child's behavior, a matter sometimes forcefully brought to our attention by the child himself. And finally, behavioral disorders are usually complicated by psychological factors which take time, and possibly other modalities, to resolve. With regard to academic categories, it is likely that more time must elapse (or educational therapy undertaken) before children show the full benefit academically of their new cognitive skills.

Figure 12

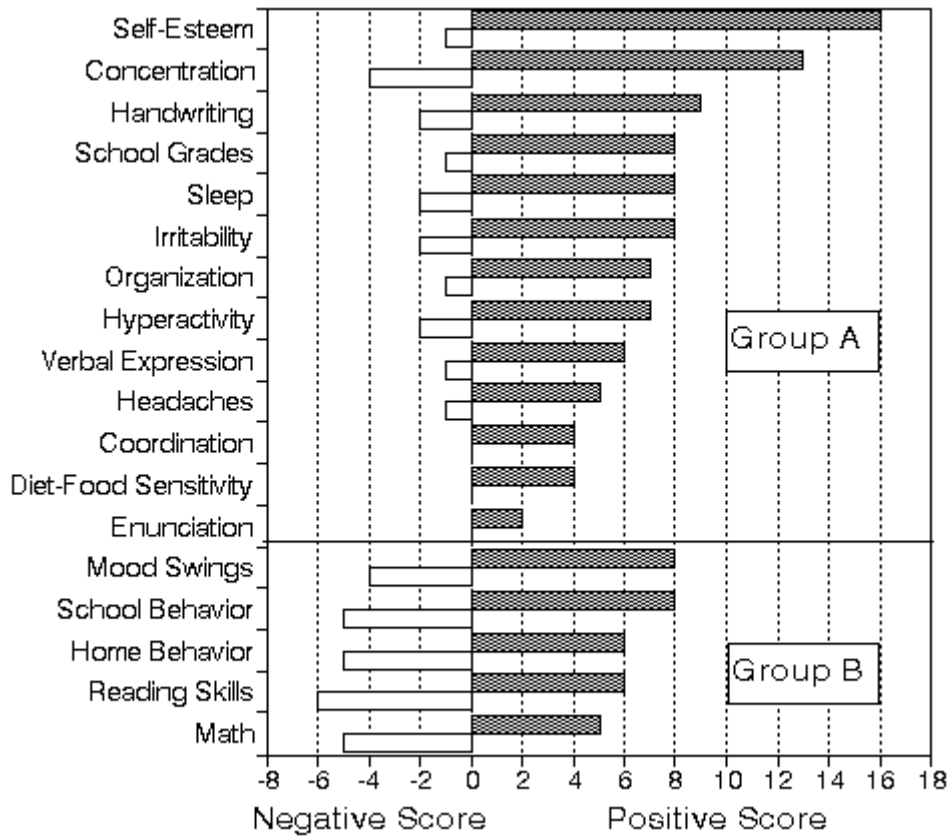


Figure 12.

Results of followup with parents on year after the initiation of training. Positive scores indicate areas of significant improvement (+1) or major improvement (+2). Residual problem areas garner a score of -1.

►DISCUSSION

The results described above demonstrate a significant beneficial effect of 15-18 Hz EEG normalization training on attentional deficits, on specific learning disabilities, on sleep disorders, on headache syndromes, and on certain adverse behaviors. With respect to the WISC-R, it was shown that for initial values less than the norm, improvements were generally well outside the range of test uncertainty. The results for the group, therefore, were highly statistically significant.

●WISC-R

One concern with respect to the WISC-R is a practice effect on retest scores, with the result that many practitioners insist on a six-month retest interval. This criterion was adhered to in our study, with most retest intervals larger than nine months. We believe

that the practice effect on the present data is in fact negligible, based on the following grounds: First, in one explicit determination of retest error with a sample of 300, after only a one-month interval only a 7-point IQ change was observed. (Wechsler, 1974) After some six to nine months, more extinction would be expected. Second, the concern about retest error diminishes if one is observing significant change in the WISC-R. In a number of the WISC-R subtests, the child is asked to stop after a certain number of errors, or by virtue of a time limit. On the retest, therefore, the child is exploring fresh ground if he is in fact doing significantly better than before. Third, significant gains were observed in those areas where long-term memory cannot have been an issue, such as Digit Span. Fourth, the gains were in fact least where a practice effect might be expected, such as Block Design and Object Assembly. Finally, we are dealing with a population which demonstrated poor visual retention in the pre-test.

The gains shown in the WISC-R are ascribed to a composite of factors. Alertness, attentiveness, and perseverance were clearly greater in the retest than before, in essentially all cases. Impulsivity was manifestly better, and test anxiety was reduced. However, there is abundant evidence for a broad range of improvements in those cognitive tasks which contribute to verbal comprehension and to perceptual organization: visual and auditory retention (Benton VRT and Digit Span), short and long-term memory (Information, Vocabulary), sequential processing (Arithmetic), inferential thinking (Similarities), verbal conceptualization and expressive language (Comprehension), visual perception (Picture Completion, Picture Arrangement), sequential processing (Coding), and visual-motor coordination (Tapping Test, Mazes).

Hence, the WISC-R improvements are attributed to a combination of behavioral and cognitive factors. Moreover, improvements in both areas appear to be directly attributable to the EEG training, rather than one being the incidental corollary of the other. The startling improvements in arithmetic score on the WISC-R, for example, are likely to be due to a combination of factors, such as improved attention span and improvements in sequential and symbolic processing skills, in addition to behavioral factors such as reduced anxiety or impulsivity.

● WRAT

The results of the WRAT show a much larger dispersion than the WISC-R test results. Some children demonstrated great strides in reading and arithmetic achievement. Others were relatively unaffected. It should be noted that the WRAT is a test of achievement rather than of ability. It may take time (or educational therapy) for new cognitive skills to manifest themselves in higher academic achievement.

Benton VRT, and Tapping Subtest of Harris Tests of Lateral Dominance.

The Benton VRT shows perhaps the most striking evidence of an effect on a specific learning disability, as distinguished from general effects on attentional mechanisms. And the Tapping Subtest of the Harris Tests of Lateral Dominance is perhaps the most graphic demonstration and of an effect on hemispheric organization, and is arguably best understood in terms of remediation of a traumatically induced neurological deficit.

● Mechanisms of Efficacy of EEG training

These findings are corroborative of a mechanism which remediates minor neurological deficits centrally. That is, the statistics of cortical activity, as manifested in the EEG, are assumed to be governed largely by the brain stem reticular formation and nonspecific thalamic nuclei. The effects of such training would be expected to be global, that is, not restricted to one hemisphere. The training apparently impacts on the processes which govern cortical activation, via a balance of excitatory and inhibitory mechanisms.

The breadth of impact of this technique implies a more universal mechanism than one specific to the motor system, or even to sensorimotor cortex. The fact that the same protocol can successfully address both symptoms of cortical hyperexcitability (seizures, motor and vocal tics, anxiety) and symptoms of underarousal (childhood depression, ADD) strongly suggests that EEG biofeedback may be a general method of achieving cortical regulation or stabilization in individuals where that is manifestly deficient.

▀ Comparison of WISC-R Data with Tansey

A comparison has been made between the WISC-R results achieved in this study and those achieved by Tansey using SMR training at Cz. The results are shown in Figure 13. The comparison indicates that Tansey's population was relatively more severely impaired. The gains are significantly higher in our study group for Arithmetic, Picture Completion, and Comprehension. They are significantly lower for Object Assembly. The other subtests show comparable gains. If account is taken of the difference in pre-test scores, the implied preference for the present protocol emerges even more strongly.

Figure 13

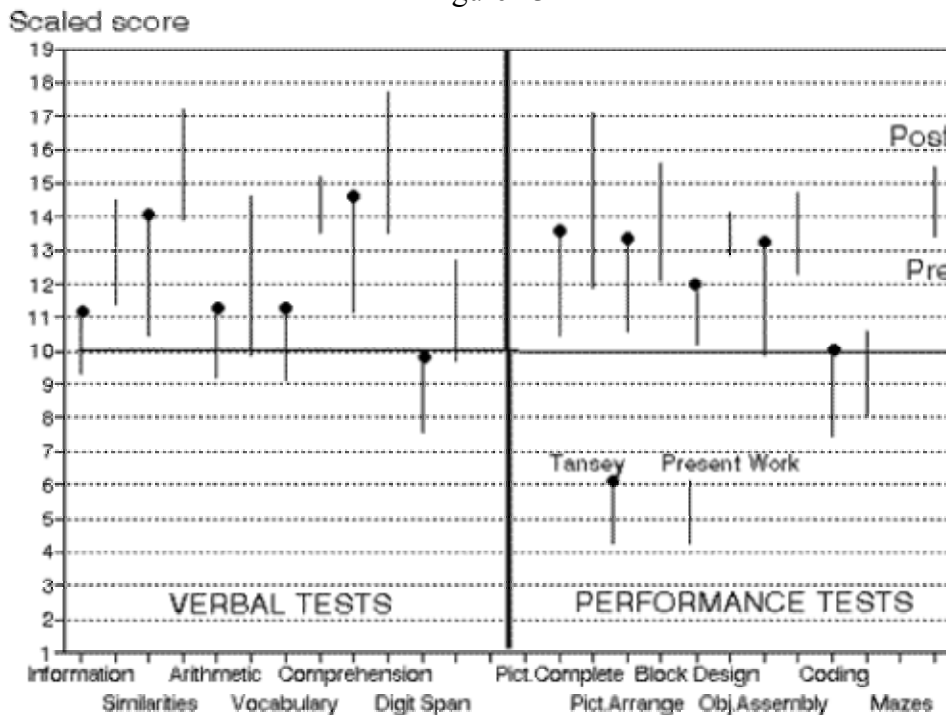


Figure 13.

Comparison of WISC-R data from the present study using beta training with that published by Tansey (1990) for SMR training. A preference for beta training is indicated.

►SUMMARY

In summary, we have documented by a variety of tests specific benefits in terms of cognitive function and academic competence of EEG training at sensorimotor cortex, and consisting of enhancement of activity in the 15-18 Hz spectral region, and suppression of excessive amplitudes in the 4-7 Hz and 22-30 Hz regions. The benefits of the training are ascribed to indirect stimulation of the central mechanisms which govern cortical activation. Striking improvements in symptoms of conduct disorder and oppositional/defiant disorder were also noted in those cases where these were present, but were not quantitatively assessed. Sleep disorders and headache syndromes were also remediated. Follow-up data indicate the benefits of the training persist. A preference for beta training vis-a-vis SMR training for remediation of cognitive deficits, as originally reported by Lubar, appears confirmed.

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