Academic Performance Enhancement with Photic Stimulation and EDR Feedback

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This study was designed to test the possibility that training with the Biolight, a combined audio/visual stimulation (AVS) and EDR feedback device, would result in positive changes in academic performance. University students who had sought the help of the student counseling staff were divided into two groups of 8 each. The experimental group received 30 sessions of the combined AVS (using only the photic stimulation) and EDR feedback. The control group received no training. All subjects were given pre-post physiological stress profiles and other psychometric testing. Results indicate that the Biolight training can improve academic performance.

Key Words: EEG, Peak Alpha Frequency, AVS, Photic Stimulation, EDR, GSR, GPA, Biofeedback, Academic Performance, Peak Performance

INTRODUCTION

The focus upon academic achievement has been highlighted in the rich technologic and artistic environment provided by institutions of higher education today. Students and other population groups such as high level executives and top athletes pursue the goal of functioning at peak capacity. Thus, it is timely that research be conducted on the many products touted to enhance performance. The purpose of this study was to test new technology that combines photic stimulation and electrodermal response (EDR) biofeedback for its effect on school performance in undergraduate college students. These students had sought help from the Western Washington University Counseling Service because of academic problems.

The device, called the Biolight, had been shown in an earlier study (Budzynski & Tang, 1998) to affect brain waves in a single session, boosting the ratio of high to low alpha (A3/A1) (Fig.1), and increasing peak alpha frequency (Fig.2).

Their pilot study involved 34 sessions of Biolight stimulation in a mode that presented a constant 14 Hz photic stimulation frequency, while intensity of the light stimulus and frequency of an auditory tone varied with EDR level. Sixteen subjects participated with six of the subjects experiencing multiple sessions. A no-stimulation "Pre" period of 50 epochs was followed by 15 minutes of stimulation, after which EEG readings at Cz (referential with ear reference and ground) were taken for 30 epochs immediately after (Post) and then at Post 5 minutes, P10, etc. The results showed that the High/Low alpha (11-13 Hz)/(7-9 Hz) magnitude ratio increased during the follow up period as shown in Fig. 1. Moreover, peak alpha frequency (PAF) also increased in the follow up period after stimulation (Fig. 2). These results

Figure 1
Mean A3/A1 Alpha Ratio at Cz
f =14 Hz N = 34

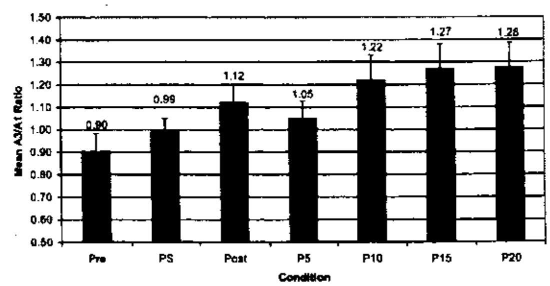
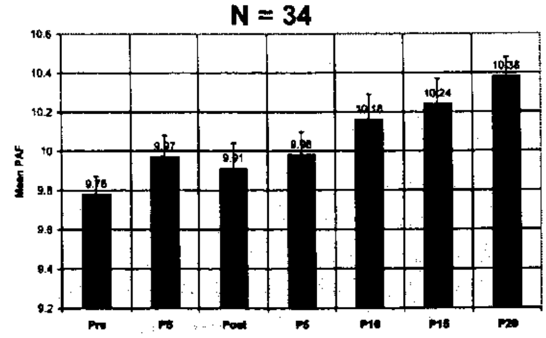


Figure 2
Mean Peak Alpha Frequency (PAF)
N = 34



served as the basis for deciding to use the Biolight, albeit in a somewhat different mode, to attempt to increase students' school performance.

The subsequent academic performance enhancement study described here, provided a series of photic stimulation/EDR feedback sessions in order to alter electroencephalographic (EEG) and EDR activity with the goal of increasing cognitive functioning and grade point average (GPA). The experimental group was compared to a control group which received the identical pre-post testing but no training.

Significance of this Study

EEG Patterns and Cognitive Performance:

A review of intellectual performance and the EEG indicates that certain alpha band EEG frequency characteristics seem to be associated with better cognitive performance. For example, Anokhin and Vogel (1996) examined 101 healthy males aged 20-45 and found that scores on the Raven's Standard Progressive Matrices (SPM) correlated positively with peak alpha frequency in the prefrontal and frontal regions. Klimesch et al. (1990, 1993) have shown that the alpha frequency of good memory performers is 1 Hz higher than that of bad performers. Later, Vogt, Klimesch and Doppelmayr (1998) found that only within the high alpha band (10-12 Hz) did power correlate positively with memory performance. A comparison of power spectra showed that within this range good performers had significantly greater normalized percent power than bad memory performers. The relationship was particularly strong during eyes open and memorizing words conditions. Jausovec (1996) showed that a comparison of gifted (mean IQ = 137) and average (mean IQ = 105) individuals produced a higher alpha power in the gifted group in the eyes open resting condition and during problem solving. Less gifted people apparently need to use more areas of the brain (more mental effort) to solve the problems and thus desynchronize more.

Working with adults, Mundy-Castle (1958) found the highest correlation (0.51) between alpha frequency and total I.Q. Saunders (1961) however, found only a low but significant correlation between subscore Digit Span of the Wechsler-Bellevue Intelligence Scale (WBI) and alpha frequency once normal intelligence was subtracted. In a similar vein, Giannitrapini (1969) divided 18 students into two groups of intelligence level based on the WAIS I.Q. scores. The high group (I.Q.s of 119-143) showed higher alpha frequencies in the left frontal area than the middle IQ group (93-118) especially while doing math (as contrasted to resting). The frontal asymmetries correlated highest with Verbal I.Q. In contrast, parietal and occipital area dominant alpha frequencies correlated highest with Performance I.Q.

Giannitrapani (1988) later found in a study with 56 11-13 year-old subjects that the power in the single Hz beta band of 13 Hz (which included activity from 12 to 14 Hz) correlated best with Verbal I.Q. scores. This narrow band beta activity, in primarily the central area, might be reflective of an EEG activity level generated when organizing information and performing mental tasks. Luria (1990) observed that lesions in this area produced intellectual deficits concerned with the ability to synthesize and automate mental activity. Considerable attention has been placed upon higher frequency dominant alpha as a marker of superior cognitive functioning. These researchers suggest that the dominant alpha frequency of 9.3-11.1 Hz is the usual range for a normal adult EEG-Olofsson, 1971). Whereas, an excessively low dominant alpha frequency of less than 8.5 Hz reflects a dysfunctional physiologic state (Markand, 1990).

In addition to the consideration of the increase of dominant alpha frequency as a discriminating measure for improvement of cognitive performance, other characteristics of the alpha band become relevant as change indicators. The extent to which the magnitude of two Hz alpha bands might change through intervention becomes interesting. For example, the ratio of magnitudes of A3 (11-13 Hz) to A1 (9-11 Hz) is markedly different between healthy adults and neurologically impaired adults. Better functioning individuals tend to have higher ratios of A3/A1. (Budzynski, 1993; Wu & Lui, 1995). If a single session of AVS appears to increase A3/A1 and PAF as it did in our pilot study what would 30 daily sessions (5 per week) do for the alpha characteristic? Lubar (1997, 1998) has reported on a study in which part of the protocol involved the use of twice dominant alpha frequency AVS presented daily for 20 sessions. These subjects showed an increase in eyes open beta and high beta even as the slow delta frequencies decreased. This would seem to be a close to ideal frequency to use if one wished to increase cortical activation while decreasing slower frequency components. In the study to be described we decided to include both the 14 Hz and a 22 Hz stimulation frequencies in an alternating pattern.

The above studies served as reinforcement to examine the alpha and beta characteristics for signs of improvement in brain activity that might be also reflected in improved intellectual functioning. The extent to which academic performance as well as these EEG parameters could be changed through intervention was a central focus of the present study.

Electrodermal Response (EDR) and Anxiety:

The use of EDR biofeedback, or GSR biofeedback as it was known earlier, to relieve anxiety has a long history. However, research in this area appeared to generate more attention in the late 70's and early 80's (Small, 1982, Fehring, 1983, Budzynski, Stoyva & Peffer, 1980). Small concluded that the unsupervised biofeedback training at home was more effective than a taped relaxation procedure at reducing anxiety. Fehring compared Benson's relaxation technique (BRT) with Benson's technique augmented by GSR feedback (BAR). Post treatment analysis indicated that the BAR group had significantly lowered state anxiety and POMS (Profile of Mood States) scores than the BRT and a control group. Budzynski et al. (1980) had incorporated GSR feedback into their sequence of biofeedback training which included EMG and temperature feedback as well. The GSR training was considered very important for clients with anxiety problems.

In this study it was assumed that a number of the students who were participating because of academic difficulties would have experienced anxiety regarding test-taking and possibly during the studying as well. The Biolight with its EDR feedback feature, augmented by photic stimulation, should therefore be an ideal training instrument.

Photic Stimulation Research:

The use of photic stimulation for changing brain wave activity can be traced as far back as Adrian and Matthews (1934). However, the work of Walter and Walter (1949) remains the classic in generating recognition that photic stimulation can cause EEG patterns to match the frequency of the flickering lights. Fox and Raichle (1985) studied the effect of photic stimulation on regional cerebral blood flow (rCBF). They found rCBF to be increased in the striate cortex through photic stimulation by approximately 28% over baseline. Diehle et al. (1998) also found significant cerebral blood flow increases with photic stimulation. Mentis et al. (1997) used PET scans with elderly subjects to show how photic stimulation can activate frontal areas of the brain.

A number of studies have been performed on numerous types of subjects, indicating that photic stimulation achieves the desired changes. Japanese researchers Kumano et al. (1996, 1997) reported the effects of an EEG-driven light/sound system in two articles in a refereed journal. The EEG was entrained by light emitting diodes (LEDs) in a goggle array, the frequency of which was driven by the EEG dominant frequency. The effect was a decreasing of depression in the first study, and stress response in the second.

Rozelle and Budzynski (1996) used Och's EEG driven photic stimulation method as the first half of a successful treatment protocol with a stroke patient who was almost 6 months post-stroke. In the second half of the protocol, neurofeedback of theta suppression/beta enhancement was used. This patient's functioning was largely restored, including the reduction of symptoms of one-sided paralysis, eyesight, speech dysfunction and cognitive deficiency. Carter and Russell's studies with photic stimulation with application to learning disorders have spanned over ten years and culminated in the awarding of SBIR grants Phase I and II thus far (Carter and Russell, 1993; Russell, 1997). The more recent research of Russell and Carter has involved an EEG-driven-light/sound device similar to the one used in this study. And lastly, in a controlled study of light/sound with mild-to-moderately demented geriatric subjects, Tan et al., (1997) reported significant improvement in standardized measures of cognition and mood over their non-treatment, attention-only counterparts.

Hypotheses Considered in This Report:

1. The pre-post GPA improvement for the experimental group (E) will be significantly greater than the controls (C) at the end of the quarter following training compared with the GPA in the pre-training quarter.

2. The pre-post EDR level improvement for the E group will be significantly greater than for the C group.

3. The pre-post dominant alpha improvement will be significantly greater for the E group than for the C group.

4. The pre-post dominant beta improvement will be significantly greater for the E group than for the C group.

5. The pre-post A3/A1 alpha band improvement will be significantly greater for the E group than for the C group.

METHODS

This study involved an experimental design in which Western Washington University students who had completed at least one quarter at this university and who had sought help from the student counseling service because of academic difficulties were assigned to either a photic stimulation-EDR group or a waiting control group.

Sample

The sample was drawn from undergraduates who had sought academic counseling services. It was negotiated that the first 10 selected would enter into the experimental training program and the remainder would be placed in a waiting list control group. This assignation of subjects was determined by the fact that there was a critical time period in which the study could be done. The quarter after the pre training quarter was used for the training. The follow-up quarter had to start after training was completed. We were not certain we could get enough subjects through random assignment into the two groups in this critical period, therefore we opted to get at least 10 experimentals started on their training before attempting to pre-test the controls. In the sample reported here, 11 were recruited into the experimental group, three of which did not complete the training. Nine control subjects were recruited, of which eight finished the post-testing. Subjects who dropped out did so because they did not like the pre-testing or the treatment procedure or simply forgot to attend sessions.

The characteristics of the groups were as follows: there was a total of 17 subjects, 15 females and 2 males, all Caucasian. Of those that completed post testing the experimental group contained one male and seven females. The control group contained one male and eight females. The average age for the E group was 25.37 and for the controls 25.12 years. Subjects were not matched on any criteria except that they had sought assistance from the Counseling Center and they had been in the University at least one quarter.

Pre and Post Testing

Pre and post testing consisted of a Psychophysiological Stress Profile (PSP) – first developed by Budzynski and Stoyva in the mid 70's (Budzynski & Stoyva, 1984). The PSP included measures of EEG activity, finger temperature, electrodermalgraph (EDG), and heart rate, in conditions of eyes open (EO), eyes closed (EC) resting, and eyes open during mental tasks Digit Span and Digit Symbol, followed by EO recovery and then EC recovery. (Note: the EDG and EDR terms are used interchangeably in this report. The J & J I-410 system uses the term EDG while we had used the term EDR with regard to the Biolight.)

Response Measures:

Pre and Post physiologic measures were obtained using the J & J I-410 system. The protocol involved a PSP of three intervals of rest, stress and recovery, while measurements were taken of EEGs from F7 and F8 monopolar (referential) montage, along with EDG, finger temperature, and heart rate. Because of the number of other response measures we could only acquire data from two EEG sites. We chose F7 and F8 as a compromise such that we could look for possible EEG signatures of depression (F7/F8 alpha band magnitude>1), as well as studying this frontal region bilaterally for signs of activation as a result of the training. The sequence was 3 minutes each of eyes open resting, eyes closed resting, followed by the stress testing which involved performing the digit span, and then 45 seconds of performing the digit symbol substitution test. Finally, the eyes open and eyes closed resting conditions were repeated (called "recovery") after the stress testing.

WAIS and WRAT Subtests:

A number of subtests of intellectual functioning were chosen from the Wechsler Adult Intelligence Scale-Revised (WAIS-R) and the Wide Range Achievement Test-3 (WRAT-3). The subtest drawn from the verbal section of the WAIS was the digit span, and the subtest from the performance section was the digit symbol substitution scale. The subscales from the WRAT were those of reading, spelling and arithmetic.

Digit Span:

The Digit Span is particularly sensitive in testing for cognitive functioning and short term memory. The subject is given a series of numbers, each series becoming increasingly longer. The subject repeats back the numbers in the series until he/she reaches a length in which he/she can no longer remember all the numbers. A second series of numbers is given, after which the subject is expected to repeat them backwards to the tester.

Digit Symbol:

The Digit Symbol test offers a symbol as a substitute for the 9 digits of 1-9. Digits are presented on a sheet and a space is given under each digit for the substitute symbol to be entered. Subjects are given 90 seconds to complete the test. This test is good for spatial performance and information retrieval. In prior testing both have demonstrated consistency, showing high correlations over the months following head injury. Test-retest reliability was .80 for the Digit Symbol Test with normal adults (p.254) and .88 for the digit span (p. 394). Alphas range from .85 - .95 on the nine WRAT subtests (Spreen and Strauss, 1998, p.421).

Paper-pencil IQ subscale tests were given by research assistants trained in testing. Other computerized tests not reported here were also obtained. GPA scores were obtained for the Fall 1997 quarter (pre-training), for the Winter quarter 1998 (during training) and for the Spring quarter of 1998 (post-training).

Treatment Procedures

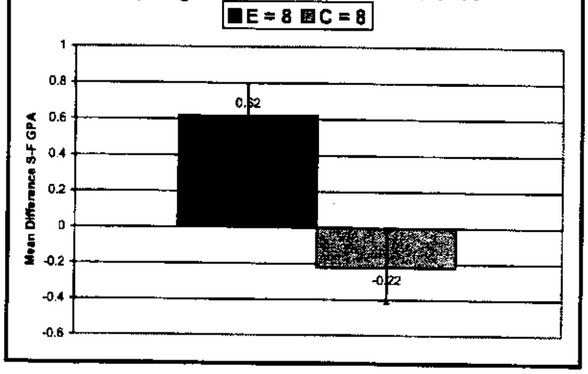
The training was administered with the Synetics Biolight for 15 minutes for 5 days of the week for 6 weeks. Feedback of the EDR from the nondominant hand was in the form of an auditory tone, the frequency of which was proportional to the EDR level. The frequency decreased as the subject was able to relax and lower the EDR. The flashing lights (amber colored LEDs) were simultaneously presented to both eyes. Subjects were allowed to adjust light intensity levels since pilot work had indicated great individual differences in preference. The sequence was one minute of 14 Hz followed by one minute of 22 Hz, and this cycle was repeated for the 15 minutes.

RESULTS

Can Photic-Stimulation and EDR Feedback improve Academic Performance?

Hypothesis 1, that the E group would show significantly greater pre-post GPA differences than the controls at the end of the pre-training quarter and at the end of the quarter following training was supported. Figure 3 shows the mean difference and standard error of the mean in the Fall 97 and the Spring 98 GPAs for both groups. This graph represents the most important result of this experiment, i.e., the GPA comparison for the quarter prior to and following the training. During the spring 98 quarter the E group did not receive any training. However, this trained group was able to maintain its higher level of academic performance even though training had been completed in the preceding quarter.

Figure 3
WWU E vs C
Spring 98 - Fall 97 Mean Diff. GPA



(Note: The Ns for the E and C groups may vary from figure to figure because of missing data (one subject did not report her GPA), or, in the case of physiological data, because of deletions due to artifacts. All artifacting was done from the original Excel sheets of 10 second data before any averaging was done. Data which appeared to indicate artifact were removed from calculation.)

Table 1 contains the t-tests results that were obtained from GPA difference comparisons between WWU groups at the end of the Fall, 1997 quarter (prior to training) and the follow-up quarter (Spring, 1998). This one-tailed value is p = 0.004. A two-tailed test of the GPA difference between groups E and C in the first quarter yielded a p = 0.155 or no significant difference in GPA before training.

Table 1
WWU GPA Differences Spring 98 - Fall 97

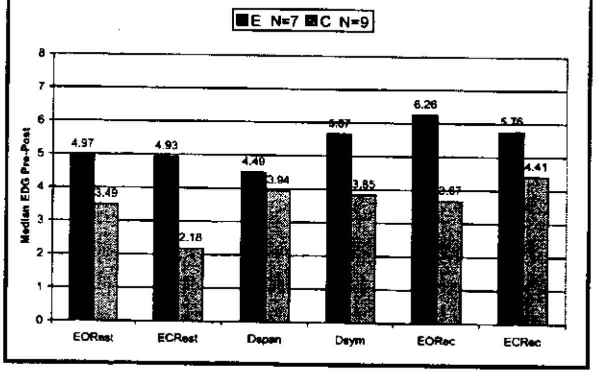
E Code	Fall 97	Spring 98	E Diff. Sp98-F97	C Code	Fall 97	Spring 98	C Diff. Sp98-F97
1	4	4	0	22	2.84	2.45	-0.39
2	2.62	3.59	0.97	23	3	1.98	-1.02
3	1	2.64	1.64	24	3.86	3.7	-0.16
4	2.86	2.94	0.08	25	3.8	3.48	-0.32
5	2.8	3.44	0.64	26	3.43	3.25	-0.18
9	2.43	2.95	0.52	28	3.23	3.7	0.47
10	1.85	2.3	0.45	29	2.08	2.73	0.65
11	2.69	3.35	0.66	30	2.53	1.71	-0.82
Sum	20.3	25.21	4.96	Sum	24.8	23	-1.77
Mean	**2.53**	**3.15**	**0.62**	Mean	**3.10**	**2.88**	**-0.22**
Var.	0.86	0.55	0.52	Var.	0.61	0.78	0.57
SEM	0.3	0.19	0.18	SEM	0.22	0.28	0.2

Diff. between E and C in 1st Quarter $p = 0.155$ 2-tailed

Diff. Between E and C Post-Pre Spring98 - Fall97 $p = .004$ 1-tailed

Hypothesis 2 was partially supported. As shown in Figure 4 the median EDR pre-post differences were greater in the E group compared to the C group at WWU. However, the variance was too great to permit significance with a t-test of any of the six conditions. When the *medians* for the six PSP conditions were tested with the Mann-Whitney U, the E group was significantly different from the C group at the 0.01 level. The E group, which was trying to lower the EDR with audio feedback as they experienced the photic stimulation actually did manage to do this even with the increased cortical arousal generated by the 14 and 22 Hz photic stimulation.

Figure 4
Median EDG Pre-Post Differences
WWU E vs. C



Hypothesis 3 stating that dominant alpha frequency would be increased more by the training was upheld in the EEG changes at both F7 (left frontal) and F8 (right frontal) sites. Figures 5 and 6 show the mean post-pre differences for each PSP condition and each group.

Figure 5
Dom Alpha at F7 WWU Post-Pre Mean Differences

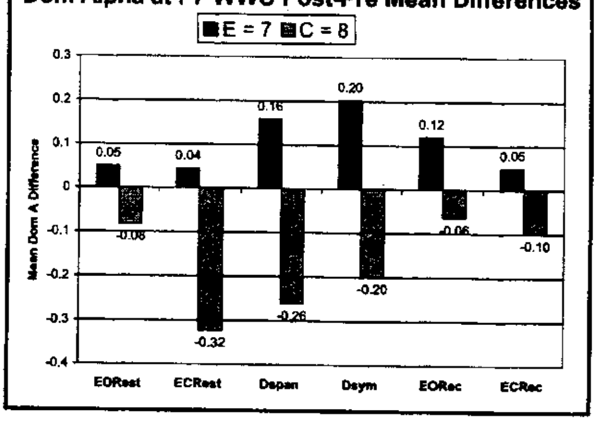
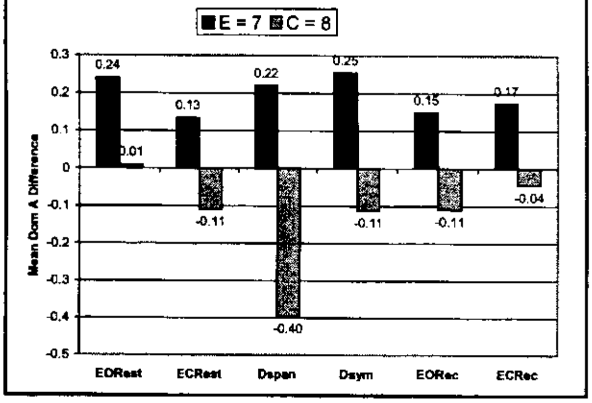


Figure 6
Dom Alpha at F8 WWU Post-Pre Mean Differences



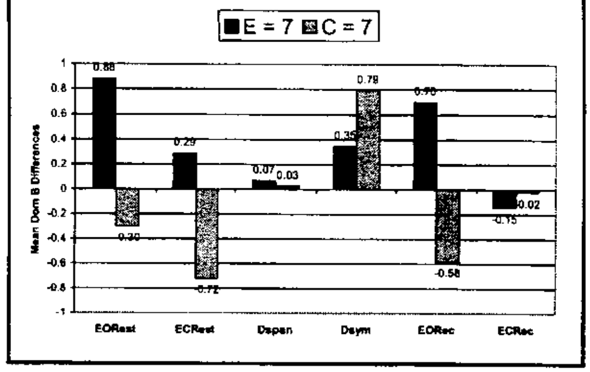
At F7 the ECRest, Dspan, and Dsym tasks showed significant differences between the two groups. That is, considering the post-pre differences, the change in dominant alpha frequency at F7 was significantly greater during these tasks in the E group as compared to the C group.

On the right side at F8, there were significant differences during Dspan, Dsym, and EORec. Thus, in the E group, the training seemed to speed up the dominant alpha frequency during several tasks, particularly during the Dspan and Dsym during which the EEGs at both F7 and F8 were increased in frequency.

Hypothesis 4 was concerned with a comparison of the groups with regard to dominant beta. It was hypothesized that the E group would show increased dominant beta frequency over the C group. Results showed that no individual condition of the PSP at F8 showed a significant difference from the control group (Figure 7). However, when the scores were combined for the eyes open conditions of EORest and EORec the E group was significantly higher on Dom B indicating a somewhat faster beta frequency in the trained group during the eyes open, non-tasking conditions.

The changes in Dom B at F7 were not significant under any condition, thus this half of Hypothesis 4 had to be rejected. Apparently, in this study, the training produced an increase in dominant beta only at F8 and only during the eyes open, non-tasking conditions.

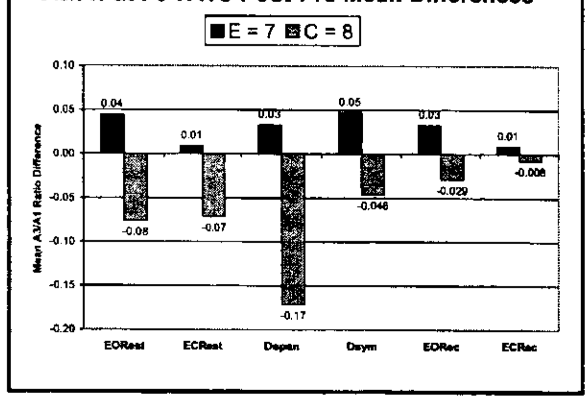
Figure 7
Mean Post-Pre Dom B at F8
WWU



Hypothesis 5 held that the trained group should produce a greater increase in the alpha ratio A3/A1 which is the ratio of the magnitude in the band 11-13 Hz divided by the magnitude in the band 9-11 Hz. In fact, there were no significant differences at F7 between the WWU groups for the individual conditions. However, when the eyes open conditions (EORest, Dspan, Dsym, EORec) were combined, the E group showed a significant increase in A3/A1 compared to the C group ($p = 0.047$).

There was a significant difference in the Dspan condition at F8 (see Figure 8). Moreover, when all eyes open conditions at F8 were combined, the E group showed a significantly greater mean than the C group as was the case with F7.

Figure 8
A3/A1 at F8 WWU Post-Pre Mean Differences



The alpha ratio of high to low or A3/A1 would appear to be seen as increased as a result of training, but only in eyes open conditions. As noted above, Lubar had reported that the twice alpha frequency AVS stimulation increased eyes open beta in the follow up.

DISCUSSION

This study was undertaken with the primary goal of enhancing academic performance. Students at Western Washington University who had sought help in the counseling department were the primary source of participants. These were students who felt they were not working up to par in their academic efforts. Based on an earlier pilot study (Budzynski and Tang, 1998) wherein peak alpha frequency and A3/A1 ratio were temporarily increased as a result of using a bio-driven 14 Hz audio/visual stimulation device called the "Biolight," and with the report of Lubar (1997) that audio/visual stimulation (AVS) at twice alpha peak frequency (approximately 20-22 Hz) tended to produce a long-term increase in eyes open beta EEG, we decided to see if this type of training would help these students achieve their goals. We therefore used both frequencies, 14 and 22 Hz, alternating each minute, as the photic stimulation, along with EDR biofeedback, which is built into the Biolight. Ordinarily, the Biolight can function as an EDR-driven AVS which means that the EDR signal controls the intensity and frequency of the light display and the volume and frequency of the sound as well. Since we wanted to use only the two discrete frequencies we decided to have the EDR function separately in that it drove a tone whose frequency was proportional to EDR level, and thus it functioned as a straight forward EDR audio biofeedback independent of the photic stimulation. Thus participants experienced light frequencies alternating between 14 and 22 Hz as they simultaneously attempted to lower their EDR levels with the tone as a cue.

Certain EEG measures were examined to see if they correlated with performance in school (GPA), as well as various paper-and-pencil tests such as the Digit Span and Digit Symbol from the WAIS, and the Reading, Arithmetic, and Spelling from the WRAT-3. These correlations were examined by Tang (1998) in her Master's Thesis. Spelling, Arithmetic, and Digit Span performance were significantly correlated with the 13-15 Hz EEG band magnitude at F7 and F8, dominant alpha frequency, and A3/A1 alpha ratio among others. Heart rate was found to be significantly correlated with beta and 13-15 Hz band magnitude.

Did the EDR decrease in the trained group? It did, but the variation in scores in these small groups did not allow a t-test to reach significance. However, the medians as tested by the Mann-Whitney U reached significance. indicating greater decreases in the E group. We reasoned that a certain percentage of students reporting problems in school might have test anxiety. Although no desensitization procedure was used we felt that the practice in lowering EDR levels would help these students feel less anxiety on the exams. Perhaps this contributed to the better GPA performance in the E group.

Did alpha dominant frequency change? Yes, a significant increase compared to the C group was seen in the E group. This was especially true during the difficult Digit Span and Digit Symbol testing. Note that this increase was seen at both F7 and F8. This could mean that the E group training had resulted in a faster processing of information in these frontal areas of the brain.

Dominant beta at F8 (right frontal) in the experimentals did not show a significant change from the controls in any one condition, however, when the scores from the eyes open conditions were summed for both groups, the E group showed significantly faster beta than the C group. This was not true however in the F7 (left frontal) measure. Apparently the training produced beta quickening only on the right side and in the eyes open states.

The A3/A1 measure did show a significant increase in the E group compared to the Cs, but again not for any one condition but rather a combined score obtained from the eyes open conditions. Both at F7 and F8 the A3/A1 combined eyes open scores were higher for the E group. Tang (1998) had found that the spelling performance scores correlated with both the left and right F7 and F8 EEG A3/A1 ratios in the pre-test baseline condition.

A 12-15 Hz band measure showed no significant difference between pre and post tests. It was expected that the training might increase the voltage in this band but there was actually a small but insignificant decrease in this band at both F7 and F8. However, significant correlations were found between the F8 12-15 Hz band during the Digit Span and Digit Symbol tasks, and the F7 12-15 Hz band during the eyes open condition of the PSP and arithmetic performance. This means that higher levels of 12-15 Hz band during the eyes open and eyes closed conditions were seen in those subjects who did the best at the arithmetic test. Other correlations showed that levels of this band at both left (F7) and right (F8) frontal areas during the Digit Symbol test predicted scores on spelling and arithmetic (Tang, 1998).

Of course the *most important measure* was the grade point average or GPA. If academic performance was to be enhanced, the E group would have to have shown a significantly greater increase than the C group after the training and follow up quarter when pre-post GPAs were considered. This is indeed what happened. In fact, the C group appeared to continue a downward course in both GPA and in a number of EEG measures as well. The E group, on the other hand, did not continue on this course but actually increased in their GPAs as well as in their EEG measures.

Of note is the fact that we did not decide to gather GPAs until the training had begun. It is interesting that the E subject who had a 4.0 pre GPA had indeed sought help from Counseling, feeling that she could somehow improve her academic performance. If we had screened for GPA we would not have included her.

In subsequent reports the results of the other variables such as the IQ testing, the Intermediate Visual and Auditory Continuous Performance (IVA), Symptoms of Stress Inventory (SOS), and Profile of Mood States (POMS) will be discussed. However, the primary goal of the study, enhanced academic performance, would seem to have been achieved.

Tentative Conclusions

A number of other researchers, discussed above, have found that faster alpha dominant or peak frequency at frontal locations and SMR (12-15 Hz) over the sensorimotor cortex voltage were correlated with better memory and performance on I.Q. tests. This small N study indicates that the use of AVS technology, possibly combined with biofeedback, might allow an improvement in academic performance by changing certain of EEG parameters to a more optimal level. The stimulation training used in this study appeared to produce enough change in the physiology of the students to boost academic performance over that of the control group even during the quarter following training. If the Spring 98 GPAs of the trained group had fallen back to an insignificant difference compared to controls , we would have been forced to conclude that the training effect was short-lived. Fortunately, this does not appear to be the case. Since the subjects were predominately female and the sample was small we would caution generalization of this effect to other student populations.

The Biolight, and possibly related devices, may be of help to those individuals who are not performing up to par in educational and occupational areas.

Note: We are indebted to Synetic Systems, Inc. and Robert Austin who supplied the Biolight units as well as financing the payment for research assistants and supplies.

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