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SCIENTIFIC ARTICLES

Eyes-Closed and Activation QEEG Databases in Predicting Cognitive Effectiveness and the Inefficiency Hypothesis

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ABSTRACT. *Background.* Quantitative electroencephalography (QEEG) databases have been developed for the eyes closed (EC) condition. The development of a cognitive activation database is a logical and necessary development for the field.

Method. Brain activation was examined by QEEG during several tasks including EC rest, visual attention (VA). auditory attention (AA), listening to paragraphs presented auditorily and reading silently. The QEEG measures obtained in the EC and simple, non-cognitive attention task that were significantly related to subsequent cognitive performance were not the same variables which accounted for success during the cognitive task.

Results. There were clear differences between relative power, microvolt, coherence and phase values across these different tasks.

Conclusions. The conclusions reached are (1) the associations among QEEG variables arc complex and vary by task; (2) the QEEG variables which predict cognitive performance under task demands are not the same as the variables which predict to subsequent performance from the EC or simple, non-cognitive attention tasks; (3) a cognitive activation database is clinically useful; and (4) an hypothesis of brain functioning is proposed to explain the findings. The coordinated allocation of resources (CAR) hypothesis states that cognitive effectiveness is a product of multiple specific activities in the brain, which vary according to the task; and (5) the average response pattern docs not involve the variables that are critical to success at the task, thus indicating an inefficiency of the normal human brain.

KEYWORDS. Attention, coordinated allocation of resources, eyes-closed and activation databases, memory, QEEG

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The relations between quantitative electroencephalography (QEEG) and clinical and cognitive- problems have been investigated for several decades (Evans & Abarbanel. 1999; John & Prichep, 2006). Individuals with cognitive deficits have shown brain activation patterns that are related to the type and severity of their deficit (Thornton. 2002). A goal of the investigations has been to identify the deviations in the underlying electrophysiological measures from normative databases so that interventions directed towards these deviations will ameliorate or improve the clinical condition. Problematic in this assumption is the frequent lack of consistent empirical documentation that the specific cognitive deficits are directly related to the deviations from the database employed. One part of this problem resides in the eyes-closed (EC) QEEG data that have been employed. For example, in understanding memory performance within a normal population, the weakness has been the lack of a well defined set of specific QEEG variables which define how success is achieved during a task. Different EC databases (Lubar, 2003) have been developed as well as databases that engage in subject in simple attention tasks with eyes-open. Developments in the Held have led to the inclusion of cognitive tasks in database development (Brain Resource Company. 2007; Skil 3 http://skiltopo. com/). A subject is compared to the normative databases on the QEEG values for the task, without reference to (he variables that are critical for the task. These databases ask the question what happens rather than what makes it work.

The EC database provides a set of values that describe the resting state of brain activity for individuals who are engaged in a 'resting' state. While the assumption is that the resting stale is a default baseline, the subjects may be engaging in any of a wide range of 'default' states. This issue is of concern to those in the field of neuroimaging (Buckner & Vincent, 2007; Raichle & Snyder. 2007). When subjects have no clear task, the resting brain shows large variations of activity that are not ascribed to performance (Gonzalez-Hernandez, 2005). Thus, the resting state is at best, an estimate of how individuals 'idle' when not required to attend, process, and remember information.

In contrast, an activation database is one that is developed while control subjects are engaged in tasks that require attention, processing. and memory (Thornton. 2001). Under activation conditions, variations in brain activation are related to the specific task. In addition, subject performance on cognitive tasks allows an examination of the associations between brain activation patterns and performance. For example, scores on tests of immediate and delayed recall on a reading task are related to measures of relative power and coherence in specific locations (Thornton, 2002).

There are differences of opinion on the relative value of the EC and activation databases (Thatcher, 1998; Thornton, 1999, 2000). An argument in favor of the EC database is the simple, relative uniformity of the EEG recording conditions (Thatcher, 1999) and high reliability values between evaluations (Niedermeyer, 1987; Oken & Chiappa. 1988). The reliability values across all frequencies for the EC condition have been shown to average around .7 (McEvoy, Smith. & Gevins, 2000).

In contrast to the passive EC condition, active tasks are dependent on many variables including the task difficulty, the motivation of the subject, and the physical characteristics of the recording environment such as the intensity of the stimuli and the room lighting. The reliability values of the activation approach for working memory and attention is .93 across the frequencies (McEvoy et al., 2000).

In addition. QEEG EC databases do not typically collect data above the 32 Hertz range. The Thornton activation database (Thornton. 2001) assesses the subject performing cognitive challenges that are difficult. in order to avoid a ceiling effect and extends the frequency range to 64 Hertz, which offers considerable advantages in certain clinical situations. For example. Thornton (1999. 2000, 2003) was able to distinguish between normals and subjects with mild traumatic brain injury- (TBI) primarily on the basis of coherence patterns s the high frequency range (32 64 IIz) in the EC. simple non-cognitive visual (VA) and auditor.' attention (AA) tasks as well as the tisk of listening to paragraphs. The results emphasized, as in the Thatcher et al. (1989) fiudy. the importance of the phase and adherence values in obtaining successful ¿sen mi nation between the groups.

The issue of using as a reference the QEEG from either a passive eye-closed mea- <_re or from an active task measure has a parallel in the Held of neuroimaging where there a debate over the default state of :hr brain that is often used as a baseline for comparison of brain activity during tasks (Morcom & Fletcher, 2007; Raichle & Sn.der. 2007). As Gonzalez-Hernandez : al. (.2005) indicated, the pre-task 'resting' □□ edition is never truly 'at rest/ McKiernan r: (2006) found in functional neuroima- task induced deactivation (TID). which > a local decrease in blood flow during an active task, relative to a "resting" baseline. TID may occur when resources shift from c-£o:ne. internally generated processing typical of "resting" states to processing required by an exogenous task. The major components of the intrinsic system have been identified by various investigations. For «ample, one group found the intrinsic sys- isn to include medial prefrontal areas, the posterior cingulate and the precuneus, lateral nr'crior parietal cortex and the anterior aspect of infero-temporal cortex (Golland ai.. 2007; Golland, Golland, Bentin. & Malach. 2008). Another group found that fee intrinsic system involves four left hemisphere regions, including posterior -arret o-occipital cortex, anterior cingulate r.-rus. fusiform gyrus, and middle frontal r.-pas (McKiernan, D'Angelo, Kaufman, & Binder, 2006).

In this study we examine two methods of understanding the relations between the QEEG variables and cognition and added a third method. The first two methods are examining (1) the relation between EC data _nd cognitive performance data collected at a different time and (2) the examination of •-he relation between cognitive performance and the QEEG variables during a task. The *'-hud* method employs the results of the second method to guide the clinical QEEG protocols to improve performance in the cognitive problems of the reading disabled, memory impaired and traumatic brain injured (TBI) patients. We propose the coordinated allocation of resources (CAR) hypothesis which slates that cognitive effectiveness is a product of multiple specific QEEG activities in the brain for specific tasks which can involve activities of different frequencies at a location as well as coherence and phase activity between locations.

In this paper we demonstrate how the QEEG measures obtained under EC. resting and simple attention tasks are not the same as the QEEG predictors of performance during the memory tasks. In addition. QEEG studies that measure brain activity with bandwidths from 1 to 64 Hz show a different set of relations between the QEEG variables and cognitive functioning than the studies that restrict the measures of brain activity to 32 Hz and less. We want to know the ongoing QEEG variables during the task which predict success.

RELATIONS BETWEEN MEASURES

As the research frequently examines microvolts, relative power, coherence and phase relations, it is important to understand the empirical relations between these measures. Corsi-Cabrera et al. (1989) summarized the relations between power and coherence across a number of studies by noting that changes in coherence occur independently from changes in EEG power.

Measures

Over the years research studies have generally defined the frequency ranges according to standard practice and have employed the scalp locations defined by the 10-20 system (Jasper. 1958). The frequency definition ranges have been: delta: 0 to 4 Hertz: theta: 4 to 8Hz; alpha: 8 to 13 Hz; beta: 13 to 25Hz. The ranges have been dependent upon hardware and software definitions as well as the preferences of individual researchers. Some studies have examined frequencies above 32 Hz (Thornton. 2000, 2001, 2002; von Stein et al.. 2000).

There are two types of data available to QEEG analysis. The first involves the activity at a scalp location and examines the different frequencies in terms of measures such as amplitude, relative power, peak frequency, and peak amplitude. The second measure quantifies the association between locations with concepts of phase and coherence. This article will employ the presented boldcd capitalized letters to represent the variables.

Activation Measures

M: Absolute Magnitude/Microvolts: the average absolute magnitude (as defined in microvolts) of a band over the entire epoch (one second).

RP: Relative Magnitude/Microvolt or Relative Power: the relative magnitude of a band defined as the absolute microvolt of the particular band divided by the total microvolt generated at a particular location by all bands.

PA: Peak Amplitude: the peak amplitude of a band during an epoch in microvolts.

PKF: Peak Frequency: the peak frequency of a band during an epoch defined in hertz.

S: Symmetry: ihe peak amplitude symmetry between two locations in a particular bandwidth-, i.e., defined as (A-B)/ (A+B).

Connectivity Measures

The coherence and phase values obtained in this research were generated by the algorithms employed in the Lexicor software. Different hardware and software companies have employed different algorithms in calculating these values. Neither the relations between these different algorithms nor the relations between the algorithms and cognitive effectiveness under activation conditions have been studied. It is not assumed that the results reported in this paper for coherence and phase relationships using the Lexicor software would be the same for the algorithms provided by other equipment manufacturers.

C: Coherence: the average similarity between the waveforms of a particular band in two locations over the one-second period of lime, and conceptualized as the strength or number of connections between two locations. Although labeled by Lexicor as coherence, from a mathematical point of view it would more appropriate to refer to it as a cross spectral correlation. P: Phase: the time lag between two locations of a particular band as defined by how soon after the beginning of an epoch a particular waveform at one location is matched in a second location.

The algorithms for coherence and phase, which were provided by Lexicor Medical Technologies, were employed in the activation database by Thornton (2001). There have been several conceptually and mathematically different approaches to describing the relationships of the frequencies between locations. Collura (2008) has provided a conceptual and mathematical discussion of these different approaches. There are 2944 variables for each subject in each task when combining all available Lexicor measures. In order to reduce the large number of variables and to be consistent with the generator concept in the EEG literature Thornton (2002) developed the flashlight calculation.

The concept of a flashlight assumes that a particular location emits a signal, in defined frequencies, which is projected to all cortical locations. The value for a flashlight variable at a specific location, and in a specific bandwidth, is calculated by summating the coherence values with the remaining 18 locations. References will employ a combination of the shorthand letters presented. For example, CA will refer to coherence alpha and RPA will refer to relative power of alpha.

There are several problems inherent in the research in the area of examining the associations between QEEG variables and cognition.

.. The first problem has been the implicit ¿sumption that certain QEEG variables relate uniformly to all cognitive abilities. This assumption has been challenged in previous research (Thornton, 2000, 2002). 1 The second problem is the assumption that the degree of activation or changes of the brain from a relevant baseline are related to success at a cognitive task. This assumption is involved in neuroimaging >:udies including positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) when brain activation during a cognitive task is related to activation al rest. 5 The third problem is the modality of the information presented to the participant, -nether auditory or visual. - The fourth problem is the assumption cmplicitly made by developers of EC databases that subject's relative standing, with respect to their QEEG values a relevant database, will remain - ughly the same when comparing values obtained under an EC condition and a task condition. In addition, it would be assumed that the deficits observed under the eyes closed (EC) condition will be rresent during the activation condition.

T*u> study examines these problems and -ic ¿>>^jations between cognitive functions' assessed by reading and auditory mem- :ey and QEEG measures in order to lay the je^csjan empirical groundwork to identify sitet:ve treatment intervention protocols.

METHODS

Participants

r n\-two right-handed participants (age -i^re to 77 years, A/=38.4. *SD*= 15.98; - " remale) with no previous history' of Al HD. I.D, or TBI participated after signer;: : -sent forms. The participants under mgt IS Signed assent forms and the parents s —rc consent forms. None of the partici- r .. -' - - ad a history of neurological problems, ic - four participants were taking medica- . - ami-hypertensive, anti-depressants). Tt is assumed that this small percentage (9.5%) of the sample would have no appreciable effect on the overall patterns. Participants were compensated financially and were free to drop out of the study at any lime or to refuse participation in the research.

Tasks

The participants completed several tasks in one session. Participants first engaged in an EC resting task for five minutes. This was followed by an AA task with eyes closed for three minutes. The participants then opened their eyes and performed a VA task for three minutes. This was followed by listening and recalling four paragraphs with eyes closed for five minutes. Following each paragraph the subject engaged in silent eyes closed recall (one minute) for each of the four paragraphs while the QEEG is measured. Then they give a verbal report of the paragraphs with no QF.EG monitoring. The next task was reading a full page of text for 100 seconds and then silently, with eye closed, recalling of the text. Then with eyes-closed, participants engaged in two delayed recall tasks. The first was a quiet eyes-closed recall of the paragraph and the second a similar approach to recall of the reading material while the QEEG is recorded. The participants then give a verbal report without QEEG recording.

EEG Recording

Brain activity was recorded using a 19 channel QEEG hardware device (Lexicor Medical Technology, Inc.). Bandpass filters were set between 0.0 and 64 Hz (3 dB points). The signals that passed were subjected to a Fast Fourier Transform (FT) using Cosine- tapered windows, which provides spectral magnitude in microvolts as a function of frequency. The sampling rate was set to 256 to allow' an examination up to 64-Hz. The bandwidths were grouped according to the following divisions: Delta: .00-4 H?, Thcta: 4-8Hz, Alpha: 8-13IIz, Betal: 13-32Hz, Beta2: 32 64 Hz. An Electro-Cap was fitted to the participant. The electrodes were positioned at 19 scalp locations according to the standard 10 20 system (Jasper, 1958) with ear linked references. The scalp was prepped with rubbing alcohol and Nu-Prep and the 19 electrodes were filled with Electro-gel. The earlobesand forehead were prepped with rubbing alcohol and Nuprep. Impedances were maintained below I0K Ohm (and within 1.5 K Ohm of each other) at all locations. Gain was set to 32000, and the high pass filter was set to off. The measurements available through the software provided by Lcxicor Medical provided the numeric values of the QEEG variables. The data were arti- facted for eye movements and EMG activity as well as other possible sources of contamination (Thornton, 1996).

RESULTS

The results are presented first by describing the associations among the tasks of EC, listening, and reading. Then the results are shown for the changes in brain activity as the participants progress from the EC task to the attention tasks then to the cognitive tasks of listening and reading.

Associations Among Measures'

To aid in understanding the research presented it is important to understand how commonly used measures relate to one another and to empirically describe their associations. Two very commonly employed measures are microvolts and relative power. Table I presents the correlations between ihe values of relative power (RP) values and absolute microvolts (M). which were averaged across the 19 scalp locations for the three tasks of EC. listening, and reading. This study included the beta2 (32-64 Hz) in addition to the commonly used beta frequency range here named betal (13-32 Hz). Although many of the relations arc significant, it is clear that the measures cannot be considered the same. The lowest associations between RP and M measures are in the delta frequency and the highest are in the alpha and beta2 frequencies. The relations between the alpha values decreases during the reading task.

TABLE 1. Interrelations between microvolts and relative power.

	Eyes Closed	Listening	Reading	Average
MD/RPD	0.10	**0.32**	0.21	0.21
MT/RPT	**0.50**	**0.57**	**0.42**	0.50
MA/RPA	**0.86**	**0.87**	**0.53**	0.75
MB1/RPB1	**0.53**	**0.38**	**0.43**	0.45
MB2/RPB2	**0.72**	**0.69**	**0.71**	0.71

Note. Bold numbers are significant at .05 level. R: Reiat-ve Power. M: Microvolt. D: delta. T: theta. A: alpha. 81: betal, B2: beta2.

Table 2 addresses the relations between the RP. M, C and P variables by presenting the correlation matrix for the EC, listening (eyes-closed) and reading (eyes open) tasks for these variables. The only significant associations involved delta and alpha. There are positive relations between RPA, MA and CA and negative relations with PA during the two eyes-closed tasks. These relations cease when participants open their eyes to begin reading. It is unclear why there are these inverse relations between CA, PA and the RPA and MA variables.

Table 3 presents the intercorrelations between the phase and coherence values. As the table indicates there arc strong associations between the coherence and phase values of the frequency measures, except for the alpha frequency under both eyes-closed tasks.

Table 4 presents the relations between age and the RP, M, P and C values across the three cognitive tasks. As the table indicates age has effects on all RP values (strongest for betal) except alpha depending upon the task; age has no effect on microvolt measures, except for MT under reading tasks. Coherence theta (CT) was the only coherence variable that was directly associated with age under the listening task. The phase values that were directly related to age were rur P\ value under EC and listening tasks as vr.. ^ P I under listening.

is summary, the associations between RP m-d M measures are strongest for alpha and bBZzl and weakest for delta across the three a.t> reported in the Table 1 (EC, listening jac reading). The

understand what specifically occurs in the QEEC) variables as the participants move from an EC task to a simple non- cognitive activation task, and to identify the QEEG variables that are related success or failure at a cognitive task. The following analysis will examine these changes as

TABLE 2. Relations between relative power, microvolts, coherence, and phase.

	Eyes Closed		Listen CD	(Eyes Closed) PD	Read CD	(Eyes Open) PD
	CD	PD				
=FC	**0.45**	**0.36**	**0.57**	**0.51**	**0.41**	0.29
HC	-0.02	0.02	0.12	0.14	**0.38**	0.16
	CT	PT	CT	PT	CT	PT
	0.24	0.07	0.2	-0.05	0.07	-0.09
ir	-0.03	-0.1	-0.05	-0.16	-0.2	-0.1
	CA	PA	CA	PA	CA	PA
=f*	**0.64**	**0.48**	**0.76**	**-0.39**	0.03	-0.08
MX	**0.45**	**-0.45**	**0.61**	**-0.42**	-0.04	0.05
	CB1	PB1	CB1	PB1	CB1	PB1
	0.01	0.05	-0.02	0.04	0.27	0.26
	-0.1	-0.22	-0.1	0.02	-0.11	0
	CB2	PB2	CB2	PB2	CB2	PB2
	0.13	-0.01	-0.01	0.08	0.11	0.19
wEZ	-0.25	-0.2	-0.13	-0.12	0.04	0.12

to« 5- : -„-ruers are significant at .05 level, R: Relative Power, M: Microvolt. D: delta, T: iheta. A: alpha. Bl: betai. C. Coherence. P: Phase.

relations between RP, M. ¿rid P values retlect non-significant -«in ihe theta, betal and beta2 handwash- Coherence and phase delta show UpcsEr. - relations to relative power of delta Relative power and microvolt -acts ^res show positive relations to coher- OEC alpha and negative relations to phase «zfei The alpha pattern doesn't exist in reading task (Table 2). Associations between coherence and um-z values are high within all frequencies, for the alpha frequency during the EC and listening tasks (Table 3). The beta2 frequency has one of the highest associations between the M and RP values as well as between the C and P values. Some of these phenomena have no clear explanation at this point in the development of this field.

the

Activation Patterns and Predicting Cognitive Success

From a clinical point of view it is helpful to

TABLE 3. Interrelations between coherence and phase values in three tasks.

^fesGcsed	Tasks				
		Listen	(Eyes Closed)	Read	(Eyes Open)
33	PD 0.96	CD	PD 0.91	CD	PD 0.80
ÇT	PT 0.92	CT	PT 0.72	CT	PT 0.71
CA	PA 0.03	CA	PA 0.04	CA	PA 0.77
ce-	PB1 0.83	CB1	PB1 0.53	CB1	PB1 0.87
CBZ	PB2 0.94	CB2	PB2 0.96	CB2	PB2 0.86

: IT -Ü T theta, A: alpha, B1: betal. B2: beta2. C: Coherence. P: Phase.

participants (1) move across tasks from EC to AA to Listening to paragraphs and (2) move across tasks from EC to VA and then to reading. The analysis of the data will also (1) examine the problem of predicting from the EC and simple AA and VA tasks to cognitive success and (2) provide a description of the state changes in brain functioning for a group of normal individuals.

TABLE 4. Relations among age, relative power, microvolts, coherence and phase in three tasks.

	RPD	RPT	RPA	RPB1	RPB2
Age (EyesClosed)	**-0.34**	-0.29	0.17	**0.47**	**0.34**
Age (Listening)	-0.29	-0.17	-0.12	**0.41**	0.25
Age (Reading)	**-0.57**	**-0.60**	-0.08	**0.47**	**0.48**
	MD	**MT**	**MA**	**MB1**	**MB2**
Age (Eyes Closed)	**0.00**	0.22	-0.17	0.14	0.23
Age (Listening)	0.02	-0.27	0.21	0.05	0.06
Age (Reading)	0.04	**-0.38**	-0.25	0.02	0.21
	CD	**CT**	**CA**	**CB1**	**CB2**
Age (Eyes Closed)	0.13	0.21	-0.01	0.05	0.19
Age (Listening)	0.14	**0.51**	0.03	0.23	0.11
Age (Reading)	0.07	0.14	0.22	0.17	-0.08
	PD	**PT**	**PA**	**PB1**	**PB2**
Age (Eyes Closed)	0.11	0.22	**0.32**	0.16	0.20
Age (Listening)	0.11	**0.45**	**0.34**	0.10	0.15
Age (Reading)	-0.05	0.20	0.26	0.11	-0.05

Note. RP: Relative *Power*. M: Microvolt. D: delta, T: theta, A: alpha, B1: beta1, B2; beta2, C: Coherence, P: Phase, Bold numbers are significant at .05 level.

CHANGES IN QEEG VARIABLES WITH CHANGES IN TASK

We report the changes in QEEG variables as the group of participants progresses from one task to the next. Selection of the variables of interest was based on a criterion of a standard deviation (SD) change of .50 or greater, using the SD of the relevant baseline task. Almost all of the changes were in the range of 0.50 to 1.00 SD for the auditory task changes and up to 2.00 SD for the visual task changes. Specifically, the QEEG obtained during AA is the relevant baseline for auditory encoding and auditory memory. Similarly, the QEEG obtained during VA is the relevant baseline for visual encoding and reading recall. In the first analysis, we examine the changes in QEEG variables when participants move from the EC task to the tasks of AA and VA and subsequently to the listening and reading tasks.

Effect Size Analysis

We will use effect size analysis to evaluate whether the task changes QEEG measures (Cohen, 1988). In order to obtain an effect size statistic *(ES)*, it is necessary to have the means and standard deviations on QEEG measures from both the EC assessment and the task assessment. The *ES* for the task is calculated using the formula: the task mean score minus the EC mean score, divided by the standard deviation of the EC distribution. This provides a change score in QEEG from EC to task in standard deviation units, thus allowing an evaluation of changes in QEEG due to the task. In addition. the *ES* is bias-adjusted for the size of the sample (Hedges & Olkin, 1985). In addition to the *ES.* we obtained confidence intervals that allow us to determine if the change from EC assessment to the task assessment is «E-iikanl. Using a cutoff of 95% confidence *i£cr»al> for a sample size of 42 subjects, we crcu ¿ted the minimum £"5 required to be «.-. that the QEEG measures obtained iroer task conditions differed from those coSccted under eyes-close conditions, with confidence. An *ES* of 0.5 meets these cooiiions. For more information, as well ki - . re details on how to calculate effect size its ^rplied to QEEG, see Thornton and Onaody (2008).

Chtmges from EC to A A

V- the participants move from an EC state AH YA state there are increases in left tem- p&il lobe activity (T3) in beta variables *PB2. PKFB1, SYMB2) and F3PA.

Ommgcs from A A to Listening

F £_re 1 shows the changes in QEEG vari- ttk:s from the AA task to the listening task. Tic changes include increases in frontal ■fci^on* of delta (RPD, PKAD, MD) and _ MT. PKAT) and occipital (02) beta2 - MB2. PKAB2). The variables which fcr-ised included frontal RPB1. PKFT and F3PA. The increases in delta probably represent artifacting issues due to eye movements.

PREDICTING LISTENING PERFORMANCE FROM PREVIOUS TASKS

Predicting from EC to Listening

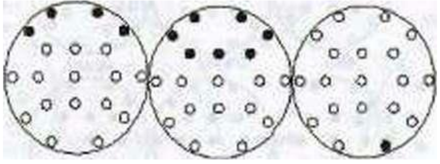
Figure 2 shows the predictors of auditory-memory under task, which indicate a predominant pattern of left hemisphere coherence alpha flashlights (F7, T3, C3, P3) and right frontal (F8) as well as PKFB1 at T5 and Cz (Thornton, 2000). These results are a recalculation of the Thornton (2000) published results employing the flashlight metaphor. This is the example of the examination of the relations between cognitive performance and the QEEG variables during a task.

Data obtained during an activation QEEG evaluation were used to develop protocols for clinical patients on a case by case basis for EEG biofeedback that was designed to improve memory. The remediation efforts improved auditory memory (2.44 standard deviations or 296%) with a group of 20 children who had learning-disabilities and

-O. -E • The changes in quantitative electroencephalography (QEEG) variables from the auditory attention sat r Te iistening task.

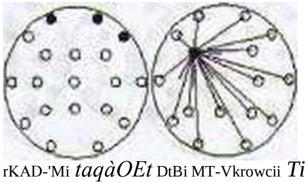
Increase In Values

MD, PKAT, MT MD. PKAD M8Î. PKAB2



Decrease In Values

BPD 1. PKFT PA

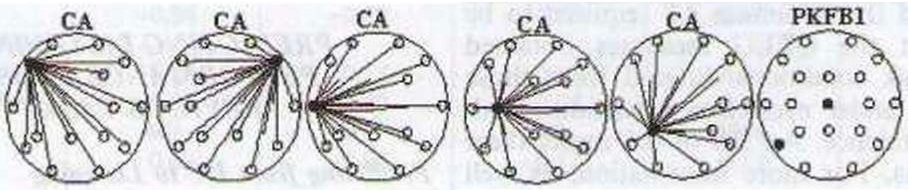


BnMUfcsy» row Delta rKAD-'Mi *taqàOEt* DtBi MT-Vkrowcii *Tie** MD^flCKMUIftiti
PKAD-Profc *hxrl Jvit* D;bi MfMtow.lt &>*i2 HUK-Puik ftrr^iUrk &H2 RPBl-Potarvi RwerB«*)
PKFT Pi*ts.* FnqwotYTkst» PA Ban Alii»

FIGURE 2. The predictors of auditory memory under task.

Predictors of Successful Recall

ADHD



EC to a

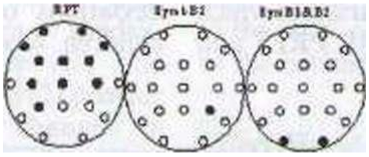
CA Coherence Aljixi PKFB1 Peak Frequency Be !at

(Thornton. 2006a; Thornton & Carmody. 2005). In a separate study. 19 participants with TBI improved auditory memory by 2.62 standard deviations (Thornton & Carmody. 2008). This is an example of the third method, the effects of intervention on cognition (Thornton & Carmody. 2009).

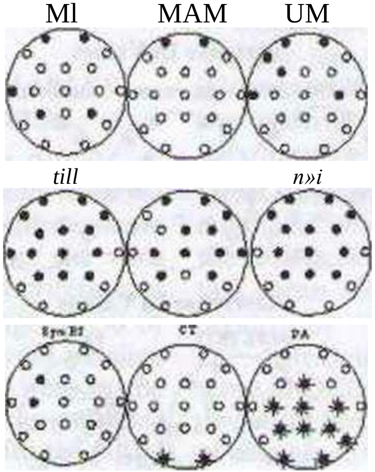
Figure 3 illustrates the predictors of auditory memory from the EC task. This is an example of the first method, predicting from cognitive measure collected at a different point in time. The positive predictors involve frontal and central RPT and posterior symmetry beta measures while the negative predictors are diffusely evident in the beta2 frequency (RPB2, MB2). frontal beta activity and posterior and central connection projections. As evident in this comparison none of the subsequent task predictors of memory performance were evident in the

FIGURE 3. The predictors of auditory memory from the eyes-closed task.

Pooitire Correlation*



Keg »tire Coirehtion*



HPT Relatr« Pavwr ThelaSttaBl Sjauretjy&ehl SymB2 SjjuinetiyBetí RPB1: Rehttvo Fbwsr Betel PKAB1: Peak Amplitude fiewl Méwvolt Beto! hCBÍ Mcmoh Befcú RPB2: Relatan řowei fiehÚ PKAB2; Peak AwpiMde Befc2 irdkMi flwMight oagin officii ofCT: Coi»rere« TV.ta PA' Phoew Alpfcs

BT task It would be expccted that a partici- pLiz'y relative value, compared to the other pLTDjipant's values, would be maintained & the change. In this auditory memory :he coherence alpha (CA) values of the {uent better performers should be :n the EC task, and thus be a predic- - recall under task. This association was : demonstrated in the data because the EC . coherence values did not correlate with :-enl recall performance.

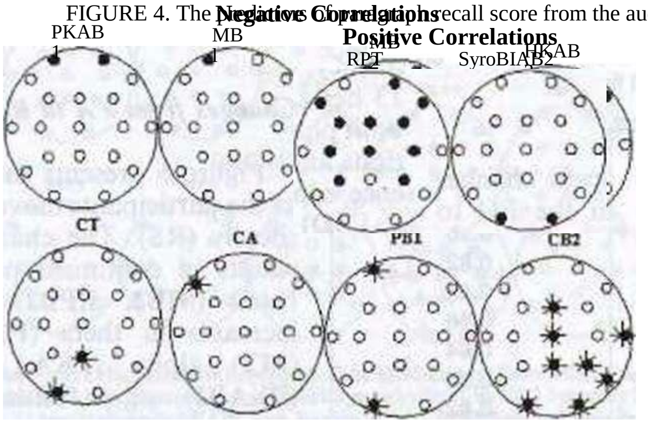
from A A to Listening

- cure 4 shows the predictors of para- recall score from the A A task. The .e relations between AA variables and pient paragraph recall ability were r. - milar to the patterns in the EC data: RPT values, occipital symmetry beta while the negative indicators - ved the beta2 frequency in diffuse loca- - addition to frontal beta measures. In the CB2 activity from the right and central locations proved to be an additional negative predictor of recall ability. In summary, brain activity during the EC or the AA tasks was unrelated to the subsequent predictors of auditory recall ability.

ACTIVATION PATTERNS AND SUBSEQUENT AUDITORY RECALL

Another way to examine the data is an analysis of the activation patterns in relation to subsequent task performance. A question that arises is whether the participants are increasing the value of the variables that are critical to task success? Examining the changes in QEEG from both the EC to AA and from the AA to listening tasks reveals no significant activation of the coherence alpha flashlights. While the change from EC to AA is not expected to induce an increase in coherence alpha values, it certainly would be expected as the participants move from the AA to listening task. An additional analysis was undertaken to determine if there was a significant change in coherence alpha

FIGURE 4. The predictors of paragraph recall score from the auditory attention task.



RI'I KalMivo :!>.-* 5>mEI : Sy*r*SY&!»; S>tnB2
Sjmxalty : S'os>.
Ar^J.f^Y ?«4l
MBl • McKftdl wbl MB3
Mkwwftft»f«2 AUdo: *Ml* AfflfUMrt» « *ahxb*
rtolijM cag;ai CT: Cob-itx-1 TW1« CA:
Ca'itr.rtt Mfàt PB1 : FW

relationships as the participants moved from the EC to listening state. None of the coherence alpha relationships showed a significant increase and almost all were in the negative direction, thus negating the possibility that the analysis was overlooking smaller increases as the participants moved from EC to AA to listening, which may be, in aggregate, significant if combined.

STABILITY OF RESPONSE PATTERN ACROSS DIFFERENT TASKS

Table 5 presents the correlations between the EC and listening tasks to describe the stability of the variables across different tasks for the relative power and microvolt measures. Table 6 presents the data for the subsequent coherence alpha predictors. As the tables indicate there are significant positive correlations between the variables under the different tasks. However, it does not appear that this stability is sufficient to employ the EC task for prediction purposes due to variability of the response pattern across these tasks. For example, the T3CA correlation is .78. providing an R^2 value of .61. leaving a large amount of unexplained variance.

Changes from EC to VA

Figure 5 presents the significant changes as the participants move from the EC to the VA task. As there were many changes involving only a few locations, the description of the results will focus on the most dominant patterns. The change from EC to VA results in large increases in relative power in beta2, right hemisphere microvolts of beta2, lateral locations for peak frequency betal, and symmetry betal and beta2 measures while the decreases in values involved broad decreases in PKFT, PKAT, RPA, PKAA, MA and posterior PKAB1 **and** PKAB2 and more centrally located and posteriorly located SYMB1 and SYMB2 measures. Connection activity decreased in CA at all locations, in CB1 lor frontal and central locations, in PA frontal locations and in PB1 frontal and temporal locations. Thus the act of looking evokes the beta2 frequency, decreases all frequencies lower than 13 hertz, and decreases connection activity, both phase and coherence, from frontal locations and between all locations in the coherence alpha variable. The greatest changes (>1SD) were the global decreases in alpha (RP, PKA, CA, PKFT) and increases in RPB2.

TABLE 5. Associations of relative power and microvolts in eyes-closed and listening tasks.

RPD	0.79
RPT	0.72
RPA	0.90
RPB1	0.90
RPB2	0.82
MD	0.81
MT	0.86
MA	0.94
MB1	0.94
MB2	0.82

Note. RP: Relative Power, M: Microvolt. D: delta, T: theta, A: alpha. B1: betal, B2: beta2. Bold numbers are significant at .05 level.

TABLE 6. Reliability of coherence measures across the tasks of eyes-closed and listening tasks.

F7CA	0.84
F8CA	0.84
T3CA	0.78
C3CA	0.75
P3CA	0.64

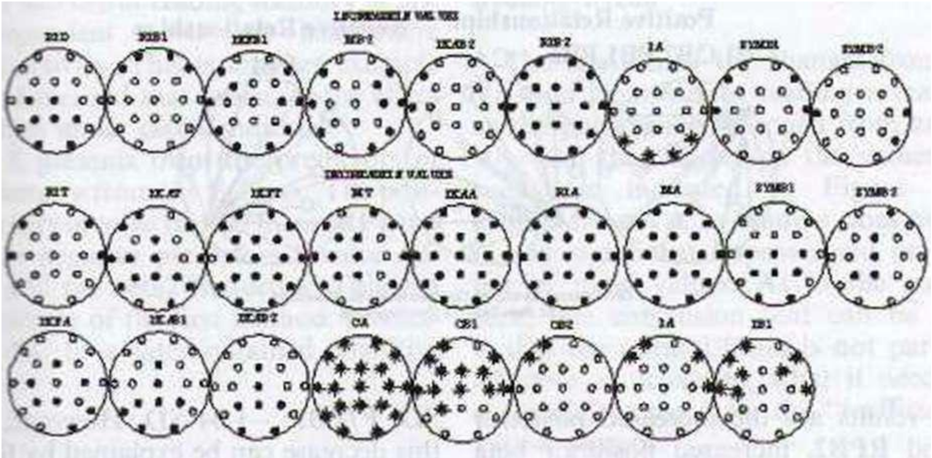
Note. C: Coherence. P: Phase, D: delta, T: theta. A: alpha, Bt: betal, B2: beta2, Bold numbers are significant at .05 level.

Changes from VA to Reading

Figure 6 presents the significant changes as the participants move from VA to reading silently (RS). The change from VA to RS results in continued posterior increases in beta2 (MB2, RPB2) along with broad increases in theta (PKAT). frontal theta (MT) alpha (PKAA, \1A) and betal (PKAB1). right frontal SYMB1 measures along with CB1 activity from posterior locations (P3, T6. 02. P4) and CB2 from posterior locations (T5. P3. Pz, P4, T6, Ol, Q2).

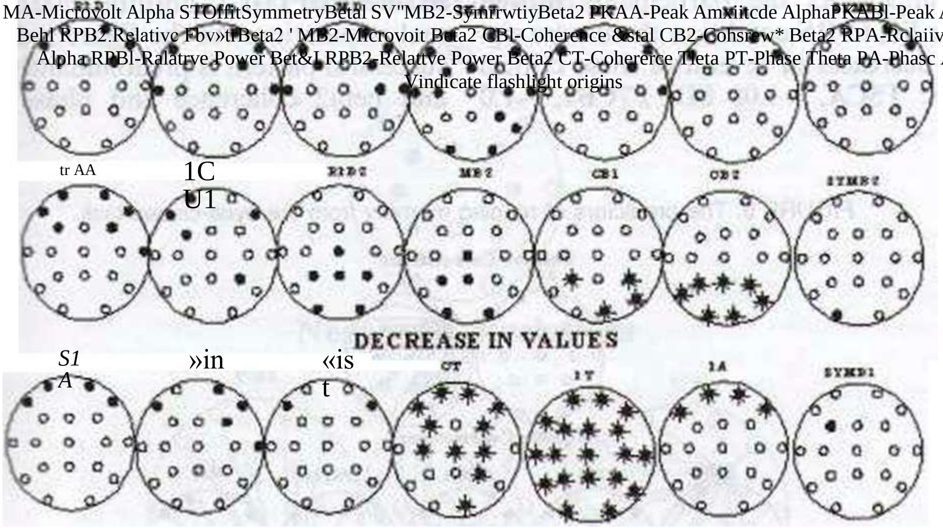
Dir_-rr-i>es were evident in frontal alpha «PA., frontal beta activity (RPBl, RPB2) broadly located theta coherence and

^Cr _ = E 5 The significant changes as the participants move from the eyes-closed to the visual attention task.



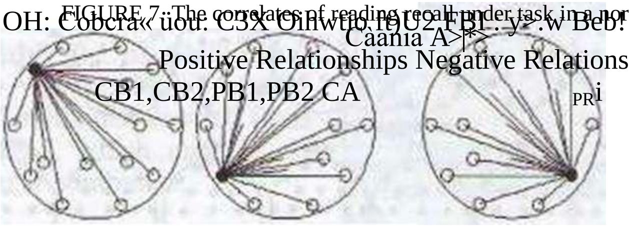
RPD-Kelalro Powtr Delta RPBl-Reastive Power Betal PKFBl-fisak Frequency Betel MB2-Mcrovolt Beta2 PKAB2 Peak Amplitude &efc>2 RPB2-Relative Power Beta2 PA-Phase Alpha RPT-Rehire ftowei The ta PKAT-Peek Amffctude The» PKFT.P«ak FrcquencyThata MT-Evfcrcnolt Thita PKAA-Rsak Amplitude Aiphs RPA-Rilstzva Powi Alpha MÄ-Mcravolt Aichs SVMBl-Sysriïf£T2Y Ëctal £tfMB2-Symir.eby Bete2 PK FA- Peak FE quciiry AJs&a PKABl-Peak Amplitude B«tal PKAB2-Peak Amplitude Bcta2 CA-Cohsrew» Aljtfia CBl-Cohorencc Brtat CB2-Coh«ence 3ct«2 FBI-Phase Betal *ind»ite flashlight origrc

3URE 6. The significant changes as the participants move from visual attention to reading silently.



RPD-Relative Poen Delta PKAD-PeakAmplitude Delta MD-Microvolt Delta PKAT-Peak Amplitixfa Theta MT-Mcrovolt Theta MA-Microvolt Alpha STOffitSymmetryBetal SV"MB2-SymrrwtiyBeta2 PKAA-Peak Amxiitcde AlphaPKABl-Peak Amplitude Behl RPB2.Relativc Fbv»trBeta2 ' MB2-Microvoit Beta2 CBl-Coherence &stal CB2-Cohsrew* Beta2 RPA-Rclaiive Povrei Alpha RPBl-Ralatrve Power Bet&I RPB2-Relattve Power Beta2 CT-Cohererce Tleta PT-Phase Theta PA-Phasc Aijfca Vindicate flashlight origins phase activity, as well as frontally located flashlights (PA). In summary, as the participant moves from VA to RS the clinically relevant results are the increased posterior MB2 and RPB2. increased posterior beta coherence activity. Successful reading involves F7 coherence activity, a top down process (Figure 7). There were no variables whose averaged value (across all 19 locations) increased greater than 1 SD in this change. An additional analysis of the changes from EC to RS was undertaken to determine if smaller changes were occurring as the participants moved between these three states, which if taken m aggregate would be significant. As in the auditory situation, there were no significant positive changes in the critical variables (F7 coherence and phase activity; T5 coherence alpha relationships). As the participants moved from the EC to RS condition there were significant decreases in several of these critical variables: T5CA, -1.08 SD; F7CB1, -1.0 SD; F7PBF -1.04 SD. However, much of this decrease can be explained by the change in state from an EC to an eyes open condition. Comparing the two attention measures (VA vs. AA) indicates that these values decrease as a result of opening the eyes. The following changes occur: T5CA, -.73 SD; F7CB1. -1.04 SD; F7PBI. -.77 SD.

FIGURE 7. The correlates of reading recall under task in a normal population.

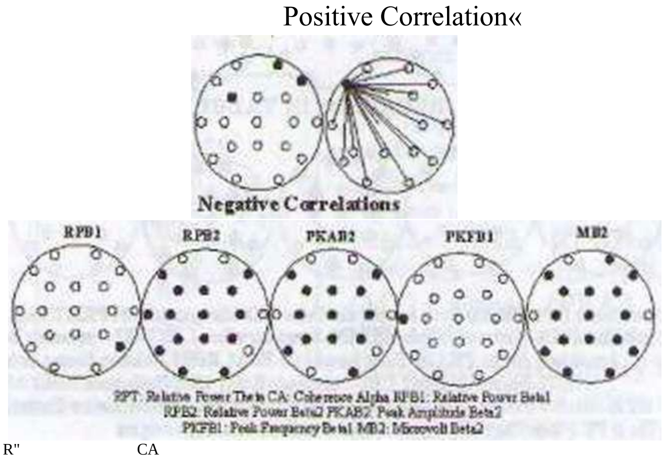


PREDICTING READING MEMORY FROM PREVIOUS TASKS

Predicting from EC to Reading Memory

Figure 7 presents the correlates of reading recall under task (Thornton. 2002) in a normal population. As the figure indicates, the successful pattern is predominantly F7 betal and beta2 coherence and phase flashlight

FIGURE 8. The predictors of reading memory from the eyes-closed task.



r.::cfr,s along with CA from the T5 loca- JC - Thus successful reading memory is pri- ■inh dependent upon left hemisphere coherence activity. This is another example of -.he third method that measures the effects f -ariables under task conditions.

> jure 8 presents from the predictors of srartmg memory from the EC task. The posi- Tt e rredictors involve frontal thcta (RP) and F~C The negative predictors involve dif- fr>r sites and the beta2 frequency. This is a r j example of the first method, predict- from EC to a later obtained cognitive —«sure.

Pre&cting Reading Memory from VA Task

Figure 9 presents the correlates from the VA task to subsequent reading recall. The ; predictors were the MD measure a central locations. Negative predictors mm ed PB1 from 01 and 02 and F4CA. Vxi of these prcdictors accurately identified the subsequent correlates under the

Visual Activation Patterns and Subsequent Reading Recall

The analysis of the changes from EC to VA and from VA to reading revealed that as the participants changed from an EC to VA task they decreased the values of the predictors indicated in Figure 7. The change from VA to reading does not result in any significant improvement or decreasing of these values. As in the paragraph task, one conclusion that can be asserted is that the normal brain is not particularly effective at activating what it needs to be successful at the task, the "inefficient activation pattern."

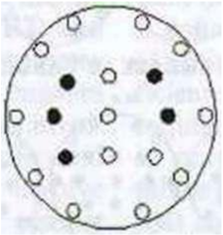
QEECS DIFFERENCES BETWEEN TASKS

Differences in QEEG Variables Between A A and VA Tasks

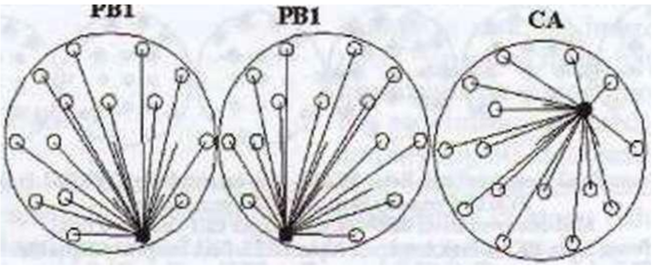
It is of some clinical value to understand the differences between the two attention tasks and two cognitive tasks, as clinician's

FIGURE 9. The correlates from the visual attention task to subsequent reading recall.

Positive Correlations



Negative Correlations



MD Mcsroit Dehft PE1: Pfease Bthl CA Co'tmttc.* Alcht

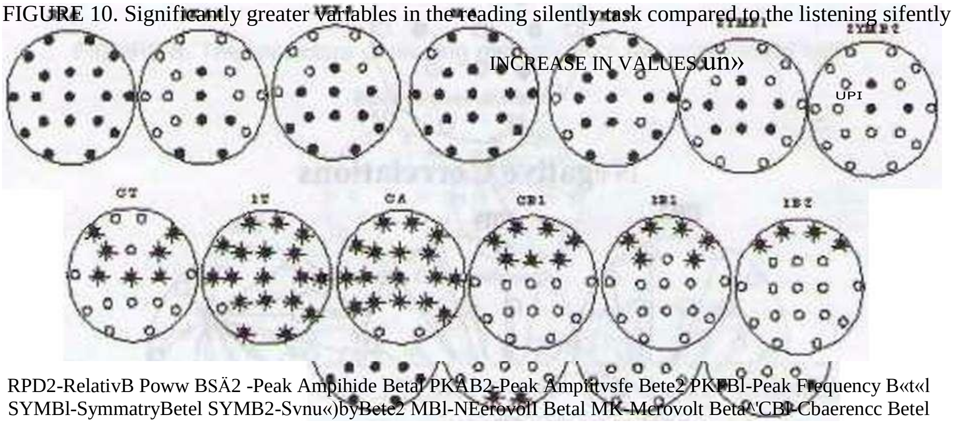
MD

may have their patients in either an EC or eyes open condition during the training and may misinterpret the meaning of the change in values. In addition, as the clinician is viewing the EC as the comparison state, a clinical error of assuming improvement in a variable may occur when, in reality, the only reason for the change maybe due to the patient opening their eyes. Only the most dominant differences will be reported. The variables which are greater in the AA task compared to the VA task include alpha (RP, M, PKA, CA) and frontal betal flashlights (CBl, PB1), frontal phase alpha and left frontal CB2 flashlights, symmetry betal measures at P3, P4. Ol. Cz, Pz and SYMB2 measures at Fz, Cz.. The VA task variables are higher in all RPB2 values, frontal RPB1, SYMB1 measures at F7, F8, T3. T4 and SYMB2 at T6.

QEEG Differences Between Listening Silently (LS) and Reading Silently (RS)

Figure 10 displays the variables that are significantly greater in the reading silently task (RS) compared to the listening silently task (LS) and Figure II presents the variables that are greater during the listening compared to the reading task. Reading has greater values than listening in frontal beta activity (RPB1, PKAB1, MB I, SYMB1), posterior beta (PKFB1, MB2, RPB2, SYMB2) and diffusely located higher values for beta2 (PKAB2). The overall pattern is one of frontal betal values higher and posterior beta2 values higher than in the listening task as well as increased CBl from occipital locations.

FIGURE 10. Significantly greater variables in the reading silently task compared to the listening sifently task.

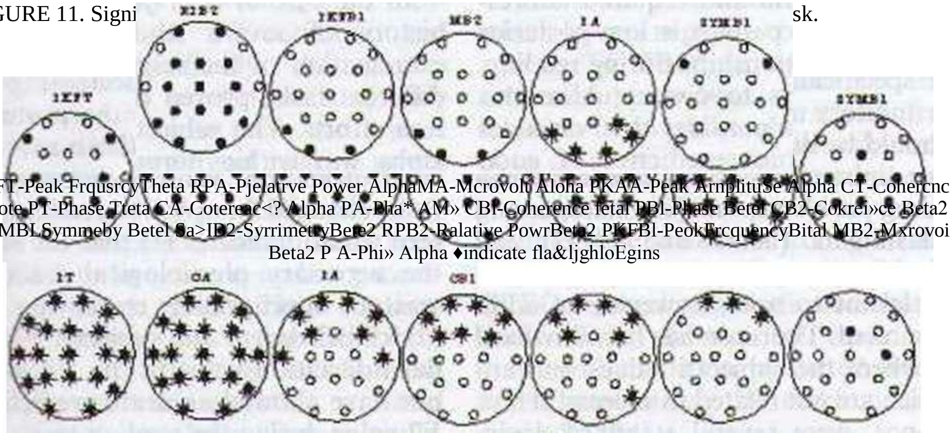


RPD2-RelativB Poww BSÄ2 -Peak Ampihide Betal PKAB2-Peak Ampiitvsfe Bete2 PKFBl-Peak Frequency B«t«l SYMBl-SymmatryBetel SYMB2-Svnu«)byBete2 MBl-NEerovolI Betal MK-Mcrovolt Beta^'CBl-Cbaerencc Betel RPA-Feiatrvc PCvm Akha PKAA-PeakAmplrtud» Alpha PKFA-Peak Frequency Alpha MA-Mcrovolt Alpha PKFT-Peak FsequsncyThste CT-Cohcrence Theta PT-Pha« Theb CA-Coherence Alpha PBl-Pha» Betal PB2-Phase Beto2 ♦indcate flashlight oiign\s

Listening silently exhibits greater values than reading for diffuse locations in the thcta

(PKFT), alpha (RPA, MA, A\: and increases in central and poster- s — metry beta I measures. Of some inter- to note is that the LS task evokes higher in the broadly located connection in the

FIGURE 11. Signi sk.



PKFT-Peak FrqusrcyTheta RPA-Pjelatrve Power AlphaMA-Mcrovolt Aloha PKAA-Peak ArnplituSe Alpha CT-Cohercnc* Ttote PT-Phase Tteta CA-Cotereac<? Alpha PA-Pha* AM» CBl-Coherence fetal PBl-Phase Betel CB2-Cokrei»ce Beta2 SYMBLSymmeby Betel Sa>IB2-SyrrimetryBete2 RPB2-Ralative PowrBeta2 PKFBl-PeokFrcquencyBital MB2-Mxrovoit Beta2 P A-Phi» Alpha ♦indicate fla&ljghloEgins

DECREASE IN VALUES

lower frequencies (CT, PT, CX.« and frontal located flashlights in the tea frequencies (PA, PB1, CB1, PB2) and in central and posterior symmetry -reasures. Thus the LS task engages IHRT frequencies more as well as invol- I —■ re activity in the coherence and associations. Both tasks involve processing, which argues against • - stein & Sarnlhein (2000) hypothesis i xbe iower frequencies are involved in processing.

DISCUSSION

Th. findings present a complex system ~ z-t ':^ adequate scientific understanding - :nt m the development of the field, r. the findings do have implications : ym EEG biofeedback intervention protocols should proceed. The results indicate (1) tasks evoke a system response which involve different locations and different frequencies; (2) focusing on a particular location, such as Cz or frequency does not adequately address the complexity of the system: (3) the high bcta2 frequency (32 64 Hz) is intimately involved in brain functioning; (4) EC and simple attention data are not sufficient to understand or predict what is required to improve cognitive functioning in normal individuals; (5) The figures and tables provided also indicate to the clinician that an improvement (from an EC database) on a variable may not relate to the effectiveness of the intervention but merely to a change in task; (6) improvement on a particular variable may have no relations to improvement of cognition; (7) interventions are generally conducted with eyes open and employ an EC database to determine interventions. However, merely opening of the eyes results in many reductions in the alpha frequency as well as other changes (see Figure 5 for specifics). The failure to suppress alpha under eyes open condition can be considered a clinical problem (Thornton, Carroll, & Cea, 2007).

More specifically when addressing problems in auditory memory in adults, the protocols should be directed towards increasing coherence alpha relationships. When addressing reading problems, the F7 coherence and phase llashlighls (beta 1 and beta2) and T5CA flashlight may require attention.

It is relevant to note, however, an additional comment. Thornton has been involved in cases where the subject's values on variables, which are not related to successful task performance, were several standard deviations below the norm and required addressing. One common pattern is low posterior coherence beta relationships during reading. There are two ways to conceptualize this issue. One way is to consider that variables are necessary but not predictive of good memory functioning. 1'he second way is to consider that any variable (coherence values in particular) which is grossly deviant from the norm may function as a hindrance to effective cognitive functioning.

The preceding discussion has focused on the clinical value of having the subject undergo specific cognitive tasks to understand the subject's deficits in QEEG response pattern on the variables which relate to performance. In addition to the value of individual task QEEG analysis, there is relevant clinical information that can be obtained from the subject's response pattern across the different tasks. Two case studies illustrate the value of the activation database.

In the first case study, a woman with impaired reading had coherence alpha values well above the norm in the paragraph listening task and her levels of coherence betal and beta2 w*ere below the norm at location F7, in addition to other locations (Thornton, 2006). The difference between her auditory and reading memory ability was 5.29 standard deviations. It is instructive in this case to ask whether the subject's beta coherence values under the reading condition reflect an underlying structural deficit in the myelinated fibers or a lack of appropriate allocation. An examination of her beta coherence values under the EC to the reading condition, indicated that the subject was increasing coherence values between the frontal locations and decreasing the beta coherence values within the posterior locations, while her F7CB2 (both raw and standard deviation values) decreased as the tasks changed from VA to reading. This pattern would indicates (I) that the subject has the necessary physiological resources, but was not appropriately employing them and (2) knowledge of the subject's F7CB2 standard deviation value in the VA task would not have allowed accurate prediction to the F7 value during the reading task.

Tn the case of a 21 year old male with a history of severe reading disability, the examination of the response pattern across different tasks proved critical to rehabilitation efforts. The subject's relative power of alpha was within normal limits under EC condition as well as all of the tasks which involved the EC. Only when the subject opened his eyes did the relative power of alpha values increase in their standard deviation value to approximately 3 standard deviations above the norm. Overall the subject's raw relative power of alpha value increased an average of .25 across all locations. thus indicating a failure to suppress alpha under visual task conditions. Once the rehabilitation protocols were set to address this problem, the subject improved significantly in his reading ability assessed by standardized testing. In this example, the subject's standard deviation value of alpha in the EC task would not have indicated the appropriate intervention. (Thornton et al.. 2007).

The purposes of the research were to (1) examine the relative value of databases obtained under different conditions in improving cognition: (2) to understand how the brain responds to different task demands: (3) to understand how the QEEG variables relate to one another. To achieve this purpose, the changes in activity levels at locations and between locations were examined during several tasks including EC, AA, VA. as well the input stages of paragraphs presented aurally and reading presented visually. The brain response patterns in each task were associated with performance on memory tasks. The results stored thai the QEEG variables measured r the recall tasks were more consistent with -science research of memory response than those measured in the EC m-i simple attention tasks. Specifically, the QEEG measures during recall show left Sty sphere involvement, which has been ss*?-- by PET to be active in auditory mem- « Nlazoyer et al.. 1993). These findings e::i>; '.hat interventions using EEG bio- itrr-i r h a v e an advantage in obtaining treatment success when selection is based re an activation database. For example, Ac; are associations between QEEG mea- *res taken under the EC condition and ac&JI memory. Specifically, the relative ^Ofccr of the theta bandwidth is directly jrsiv-xi to memory while there are inverse f-nroiLs with microvolt and relative power .. —- of beta2 bilaterally in central and r regions. However, the theta fre- in the EC condition has not been ««coated historically with effective cogni- ixrrformance (Harmony et al., 1990) J~ould not be a recommended protocol to improve auditory memory.

The locations that were most strongly associated with memory performance were toe: lifted using the flashlight concept. In ibc auditory memory task, the greatest asso- :::-.> to performance are with the coher- .iipha flashlight activity in the left r«:— -phere and right frontal locations. Pre- ■ PFT research has confirmed the role *si* the left temporal lobe (T3) and left frontal ^{r}~ ' nations in auditory processing and ata£ror\ memory (Mazoyer et al., 1993), . role of the right frontal lobe (Henson, v^I ce. & Dolan, 1999) during recall, as v : I as the dominant role of the left hemi- sccere in verbal processing.

The current study identifies coherence ¿ir.-u* ^n a contributor to the left hemisphere functioning. The predictors from EC - rare 3) and AA (Figure 4) do not fit well - previous PET research, or with present science understanding of anatomical ning and previous QEEG research - v.-. has identified theta activity as a predictor of cognitive abilities Harmony et al., 1990. Lubar et al., 1995).

In the reading task, improved performance is associated with sources of coherence in beta from left frontal region (F7) as well as sources of coherence in alpha from and T5CA activity. The previously researched identified role of the left hemisphere in language processing overlaps with these QEEG findings. The predictors from EC (theta) and VA (delta) do not fit well with previous QEEG research that indicated that elevated levels of left hemisphere theta and delta under EC condition predicted poor educational evaluations in children (Harmony et al., 1990).

There are also specific QEEG variables which have a negative correlation with recall scores (T6 PB1). In the reading task the increased phase beta activity from the T6 location is inversely related to memory. EC data or attention task data do not provide the relevant information to formulate effective interventions, while activation QEEG correlates of cognition provide the necessary information for highly effective interventions. Figure 6 indicates that reading is predominantly a bottom up processing task in a normal population with increased microvolts of beta2 in posterior locations and posterior flashlight activity (coherence betal and beta2). However, successful reading involves F7 coherence activity, a top down process (Figure 7).

The results presented in this paper suggest a coordinated allocation of resources (CAR) hypothesis of cognitive effectiveness. The CAR hypothesis states that effective cognitive functioning is determined by multiple specific variables acting in unison to achieve optimal performance and that these variables can be different in different tasks. The QEEG variables that are related to performance include activity in the beta frequency at specific locations as well as the coherence and phase relationships between locations in specific frequencies. While there are significant correlations between the attention tasks and memory performance, the QEEG variables identified in the attention tasks are not the variables that account for success during the memory task and thus arc not sufficient to develop an appropriate intervention protocol using

EE G biofeedback. Both reading and auditory memory tasks require different sets of resources for success. We cannot assume that there is a single intervention protocol that will broadly affect reading and auditory memory as different tasks require allocation of different sets of QEEG variables.

In addition, the data document that the human brain does not activate the necessary variables for success in a task. For example, coherence alpha values in the auditory task do not increase as the subjects move from an AA task to the listening to paragraphs task. One conclusion that can be reached is that the normal brain is not efficient or effective in its activation response pattern. This phenomenon can most succinctly be called the "inefficient activation pattern." This conclusion, if validated in a larger sample, has significant implications for the EEG biofeedback field and education. If the resources are available but just not employed correctly, interventions become pragmatically easier to accomplish then trying to "build" connections which don't exist. The normal human mind is not efficient at activating the necessary correlates of effective cognitive functioning, as indicated by the cognitive inefficiency hypothesis.

There are, however, patterns of relations between variables across tasks which are clinically important to understand in determining protocol interventions. These patterns need to be understood in addressing the cognitive ineffectiveness of the LD, ADHD and TBI patient if we are to obtain the desired results.

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Direction of SMR and Beta Change with Attention in Adults

Etienne Vachon-Prcsscau, M Sc André Achim, PhD Aimce Benoit-Lajoie, BSc

ABSTRACT. *Introduction.* The aim of this study was to clarify the interpretation of sensory- motor rhythm (SMR; 13-15 Hz) and beta (16-20 Hz) changes with respect to attention states.

Method. For this purpose, EEG was recorded from 11 participants during (a) a multiple object tracking task (MOT), which required externally directed attention; (b) the retention phase of a visuo-spatial memory task (VSM), which required internally directed attention and avoidance of sensory distraction; and (c) the waiting intervals between trials, which constituted a no-task-imposed control condition. The 2 active tasks were consecutively presented at 2 difficulty levels (i.e.. easy and hard). Two analyses of variance were conducted on EEG log spectral amplitudes in the alpha (8-12 Hz), SMR,'and beta bands from 1-3. F4. C3, C4 and P3, P4.

Results. The first 15 analysis compared the MOT to the VSM by difficulty levels and revealed a significant task effect ($p < .0005$) but no effect of difficulty. The results showed that externally directed attention (MOT) resulted in lower values than internally directed attention (VSM) in all three bands. The second analysis averaged the difficulty levels together and added the no-task-imposed reference condition. The results again showed a significant task effect that did not interact with site, hemisphere, or, more important, band. Post hoc tests revealed that both MOT and VSM produced significantly smaller means than the no-task-imposed condition. This pattern of log-amplitude means and the lack of task interaction with any other factor indicate that task-induced attention reduces EEG power in the same proportion across the 3 bands and the 6 channels studied.

Conclusions. These results contradict a frequent interpretation concerning the relationship between the brain's aptitude to increase low beta in neurofeedback programs and improved sustain attention capacities.

KEYWORDS. Alpha, attention, beta. EEG. Neurofeedback, SMR. spectral

INTRODUCTION

Neurofeedback programs for attention deficit hyperactivity disorder (ADHD) involve behavioral training sessions designed to modulate the EEG spectral contents. The aim is typically to reduce excess theta EEG activity (5-7 FIz) and to increase sensory- motor rhythm (SMR; 12 15 Hz) or low beta activity (16 20 Hz; Monastra. Monastra, & George, 2002). These targeted changes are based on quantitative EEG (QEEG)

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rations and arc often assumed to y correspond to increased control over and hyperactivity. In sharp con- to this literature, event-related studies present activation as reduced ade over both alpha and beta bands .heller & Lopes da Silva, 1999). experimental data linking EEG Huelo increased attention are scarcc. it possible that such event-related have no parallel in general atten- I)»JC ¿Lates. The motivation for this study »_• 10 better identify the type of modulation m SMR (13 15Hz) and beta band (16- 31 rü» during sustained attention states, Hi 111 > compared to a situation in which ac t£ik is imposed. This purpose is meant contribute to our models of how neuro- may improve attention. A few stu- i - --port the association of increase SMR t increased attention capacity. For r. Egner and Gruzelier (1994) observed >MR enhancement training improved psrk nnance in both visual and auditory tests. Moreover. SMR can be inter- a sensory-motor idling rhythm it to occipital alpha that indirectly visuo-spatial attention. Indeed Croft. Dominey, Burgess, and (2003) observed alpha enhancement .attention benefits from an active inhibi- : M all visual inputs or of selected parts of veual field. Correspondingly, learning to SMR in ADHL) could simply be ig to inhibit the sensory-motor system. t„ mastering how to get calm. Thus, increased SMR directly comes from activity in an attention network or ras >er,>ory-motor disengagement that lacil- nt» ¿/.ention is still debatable.

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lz ± >imilar fashion, increased beta (15- SMiz) amplitude prescribed for ADHD is : - > meant to directly support attention m . alleviate symptoms of inattentivcucss *Ii-jc? á¿* Gruzelier. 2004). Indeed, ADHD has been reported to increase r be ta in responders in a manner -ci> correlated with improvement in a us performance test (Loo. Hopfer, - . wV Reite, 2004). Nevertheless, the m.f -:nship of beta enhancement with ved attention remains uncertain since decreasing EEG amplitude over this range of frequencies is sometimes prescribed to increase concentration in high-level executives (U.S. Patent No. 5,740.812, 1998). The rational supporting these opposite prescriptions for increased attention capacity could be simultaneously correct if beta was associated with good attention in opposite directions in children and in adults. This paradox could also be overcome with an alternate view, in which increased beta might represent inhibition or disengagement of a system that hinders attention rather than directly reflect a better attention state. Hence, better atten- tional capacities could be an indirect effect of reduccd background processing reflected in increased beta. Although high beta (above 20 Hz) seems to characterize rumination in depression (Demos, 2005), the low beta band could represent an idling state, akin to the neighboring alpha and SMR bands.

Ray and Cole (1985) approached the relationship between EEG and attention differently. They presented evidence that alpha activity reflects attention demands (external vs. internal attention), whereas beta activity rather reflects emotional and cognitive processing. They contrasted several "external" and "internal" tasks, in which attention must respectively be paid to the external environment or directed to internally held information while resisting distraction from external stimuli (e.g., during mental arithmetic). Internal lasks, which they called "rejection tasks," were characterized by larger amplitude relative to ihe external tasks (which they called "intake tasks"), in both parietal lobes, for each 41 Tz-wide band from 8 to 20 Hz. Moreover, all these bands had more energy in the right (R) hemisphere than in the left (L). Finally, their results indicated significant interaction of attention demand (external vs. internal) with hemisphere. These interactions are however questionable, because the analyses were carried on EEG power, rather than on its logarithm, such that even strictly proportional reduction could appear as significant interaction. For instance, the 16 20 Hz band R-L difference was 29 units for internal and 37 units for external, but the corresponding (R-L)/ (R + L) ratios were, respectively, 0.130 and

0.135, indicating that the hemisphere differences were nearly proportional to the means. The increased alpha and beta amplitudes observed during the external tasks relative to the internal task arc consistent with the active inhibition hypothesis. From a strictly logical point of view, it remains possible that increased alpha reflects sensory input inhibition, whereas increased beta (sought in neurofeedback programs) would reflects increased processing involvement on internally held information.

Although this paradigm revealed locus of attention to be an important alpha and beta band modulator, the Ray and Cole study lacked a neutral control group to help interpreting the difference between the attention demanding internal and external situations. The object of our study is to clarify the relationship of S.MR and low beta with attention in normal adults by revisiting the external- internal paradigm with the addition of a neutral no-task-imposed condition. This constitutes a preliminary step to clarify the function of increasing beta through neurofeedback in children w^{r}ith ADHD.

The main hypothesis of this study is based on the event-related studies and proposes that alpha. SMR. and low beta are reduced in amplitude when one of its supporting systems is engaged. Because the attention tasks used do not specifically require sensory motor inhibition, we expected that any spectral difference with the control no-task-imposed condition would consist in amplitude reduction. In line with Ray and Cole (1985), we hypothesized that the internal task would show larger amplitude than the external task in any affected band. In addition to our main hypothesis (reduccd EEG amplitude for the external task relative to the internal task), we also expected both experimental tasks to show reduced EEG amplitude compared to the control no-task-imposed condition.

METHOD

Participants

Our study was approved by the ethics committee of the Department of Psychology of Université du Québec à Montréal. Twelve undergraduate students (22 30 years old) w-ere recruited, signed informed consent, and received S25 after their participation in the EEG recording session. Data from one participant had to be excluded because of technical problems.

Experimental Design and Procedure

Two tasks were designed to share the same visual and response interface and were presented at two levels of difficulty (easy and hard). The first experimental condition consisted in a multiple object tracking task (MOT), in which the participants visually tracked designated targets among moving stimuli. The second experimental condition was a visuospatial memory task (VSM), in which the participants had to keep in mind the spatial positions of the stimuli designated as targets. The conditions differed in that the stimuli moved randomly in one condition and temporarily disappeared in the other. Although both tasks recruit the participants' attention toward the spatial location of targets, the MOT and VSM are respectively "external" and "internal" tasks, or "intake" and "rejection" tasks in the sense of Ray and Cole (1985). Indeed, the MOT commands an intense external focus because the participants have to simultaneously follow selected moving objects on the computer screen, whereas on the other hand the VSM task, during the period of stimulus disappearance, requires avoidance of distraction and focuses on the internal representation of the positions to remember.

The MOT trial's procedure consisted of several steps. First, the participant's EEG was recorded during a 6-s period preceding the onset of each trial while the display screen was blank. These EEG data were used as a control condition in which no specific task demand was imposed on the partici- pants; Six to 12 identical blue small squares (1 cm") then appeared on the while screen of the monitor. Half of them blinked for 2 s, which defined them as the targets. All objects then moved haphazardly for 10 to 30 s (during which the EEG was collected fc- tins condition). After the stimuli stopped mr.-mg. participants were required to iden- Tfy targets with the mouse. If the partici- ■ntr'- lost track of some of the targets, they «BTÎ isked to click outside the experimental *ízí*—–< rather than guess. Finally, feedback CB ibe trial was provided as the proportion . erectly identified targets along with the ňptay of the correct positions.

To ^xsess whether the tasks' dilTiculty was mt snportant predictor of EEG fluctuations, ■ae MOT was presented at two levels of 4Hkuit> (i.e.. easy and hard). These diffi- CTÉT. eseis were produced by manipulating: Ac cumber of objects, l he speed of move- ~~T--~~ the predictability of direction change jr -i:\idual dots, the task duration, and Ar -¿už of the frame inside which the objects

The VSM trial's procedure consisted of wmà^i steps. The EEG was recorded during *m.* r-enod preceding the onset of the task •fait the screen was blank. Between 6 and JT snail squares, identical to those in the liOT condition, then appeared on the screen *x* nsdom positions. A cross was inscribed ■B.r half of the squares to define them as •Ac -.-¿eis. The participants were given —1 ' i ted lime to observe and memorize tar targets" locations. At their signal (mouse £âc.t>. ¿11 the squares disappeared for a of 10, 15, or 30 s (during which the SO -aas collected for this condition). After the squares reappeared ai their initial putEZons. the participants were required to âcx with the mouse on those previously dtf-vd as targets. As in the MOT task, rants were asked to click outside the zone rather than simply guess. Fca2 feedback on performance was given is i-ř :nal success rate along with the •isiranon of the correct positions.

T-c VSM task was also presented at two jfeff-. • • levels, produced by manipulating: àr number of objects, the size of the frame rax which object were presented, and the t'umion of the retention period.

A panici pants were exposed to both Mi- a: both difficulty levels. The experi- ■L- anon contained 48 trials, presented in Acrraimg blocks of 12 of the same type axe difficulty level. The starting task was counterbalanced across participants, but the two easy levels always preceded the two harder ones.

Electrophysiological recording and data preparation.

The EEG was recorded through a 128- channel BioSemi ActivcTwo system with linked cars reference. The electrodes of interest were those corresponding to the international 10/20 system positions frequently used in neurofeedback: F3, F4, C3, C4, along with the P3 and P4 sites used by Ray and Cole (1985). The EEG signal was filtered with a 0.1 to 45 Hz band pass and then digitized at 256 Hz. T he EEG analyses were conducted only on data acquired during the 6-s blank screen stage separating the trials (no-task-imposed) or during the movement or retention intervals of the two tasks.

Trials with behavioral errors were excluded from analysis, as the error could reflect lack of attention, but the waiting period that preceded them was retained for the no-task-impose condition. All EEG epochs retained for analysis (MOT, VSM, and control no-task-imposed) were broken into nonoverlapping l-s segments, which were inspected visually, blind to condition, and rejected if they contained an artifact. Each retained EEG segment was windowed (raised half cosine on 0.1 s at both ends) and Fourier transformed. The individual spectra within each condition were averaged in the amplitude domain within subject. The resulting average amplitude spectra were then transformed to their base-10 logarithmic values for statistical analyses. The choice of these different units for averaging was based on ranking the mean spectrum among the individual spectra contributing to the mean. This was successively done for amplitude, power, and log power. The form of daia for which the mean ranked closest to 50% (the median) across the frequency bands from 1 to 25 Hz was retained. This resulted in applying a logarithmic transform to the averaged amplitude within each participant and condition. 1'he log amplitudes of the various 1-Hz-wide bands within the alpha (8-12 Hz), SMR 113-15 Hz), and low beta (16-20 Hz) bands were averaged together as a final step before statistical analysis of log spectral amplitudes.

Statistical Analyses

Statistical testing was done with a repeated measure analysis of variance (ANOVA), using SPSS MANOVA and by applying the Geisser & Greenhouse correction for effects with more than two levels: in those cases, the degrees of freedom reported are the reduced ones. A first ANOVA. ignoring the waiting condition, implemented the completely within-subject design: 2 Tasks x 2 Difficulty Levels x 3 Bands (i.e., alpha, SMR, low beta) x 2 Hemispheres x 3 Sites (i.e.. frontal, ccntral. parietal). Such five-factor analysis yields 31 statistical tests. The effects of Band, Hemisphere, or Site without interaction with Task or Difficulty are not relevant to the purpose of our study. Their presence, however, increases the risk of a type I error because any interaction of Task or Difficulty with Band, Hemisphere, or Site would justify concluding in a Task or Difficulty effect. Consequently, a Bonferroni correction was applied, which set the per-test significance level to .05/8 = .00625. Significant effects not involving Task or Difficulty are reported but were not further explored into simple cffccts or pairwise differences.

Because the first analysis showed no effect of difficulty, the easy and hard conditions could be averaged together within task for the purpose of a second ANOVA. which included the no-task-imposed control as a third level for the Task factor. This analysis (without the Difficulty level) tested 15 different effects, from which only the 8 involving the Task factor were directly relevant to this study. For the same reason as for the first ANOVA. the pcr-test significant level was set at .05/4 = .0125. The comparison of the no-task-imposed condition with each of the other two tasks was a priori justified and the critical level for these contrasts was set at the usual .05 per test.

RESULTS

Behavioral Results

The success rates lor the easy conditions were 96.3% of MOT trials and 98.2% of VSM trials. The success rates for the harder conditions were 68.5% of MOT trials and 71.3% of VSM trials. EEG results Figure 1 illustrates the means for the five experimental conditions over the six channels of interest. Given the lack of interaction involving band (see next) and the greater interest for the SMR and beta band (because neurofeedback in ADHD targets these more than alpha), the alpha band was omitted to simplify the figure.

The first ANOVA (Task x Difficulty x Band x Hemisphere x Site) showed 5 significant effects out of the 31 tested. Among the effects of interest, that is, those involving Task or Difficulty, only the main Task effect was significant, ƒ\ 1, 10) = 33.84. *p* < .0005. The main Difficulty effect was clearly absent. /■(I, 10) —0.39, /.» = .547. as well as any interaction effects involving Difficulty.

Of the effects involving neither Task nor Difficulty, all three main effects were significant: Band, *F(* 1.6, 16) -33.34, /;<.0005; Hemisphere. *F* 1, 10)= 177.68. /x.0005; Site. ¿(1.59, 15.9) = 492.82. ¿><.0005; as was the Hemisphere x Site interaction. F(1.79. 17.9) = 74.14,/?<.0005.

For the Task effects, the means were 0.959 (±0.027 *SEM)* for MOT and 1.027 (±0.024) for VSM. For the Band effect, the means were 1.136 (±0.036) for alpha, 0.991 (±0.036) for SMR, and 0.853 (±0.022) for beta. The Hemisphere and Site means are reported through their interaction: for frontal, central, and parietal, respectively, the means were 1.123 (±0.023). 0.925 (±0.028), and 0.713 (±0.025) for the left hemisphere and 1.162 (±0.025), 1.07C (±0.032), and 0.968 (±0.029) for the riglv hemisphere. This interaction thus indicate that hemisphere difference grows fron front to back (0.038, 0.145. and 0.25i respectively). Because the measures wen in log units, these R L differences arc alst the logarithm of the R/L ampliludt ratio.

The real interest of our study lies in th< comparison with the condition in which n< task was imposed on the participants Because the initial ANOVA indicated tha the two difficulty levels were too simila to be reflected differently in the EEC

.RE 1 Mean log-10 amplitude in the multiple object tracking task (MOT; easy and hard), the visuospatial rer-cry task (VSM; easy and hard), and the no-task-imposed conditions in the sensory-motor rhythm jSMS and the beta bands over f3, f4, c3, c4 and p3. p4. note. Error bars represent standard errors of re Tjeans.

(1 MOT easy ■ MOT hard nVSM easy ■ VSM hard BNo-task

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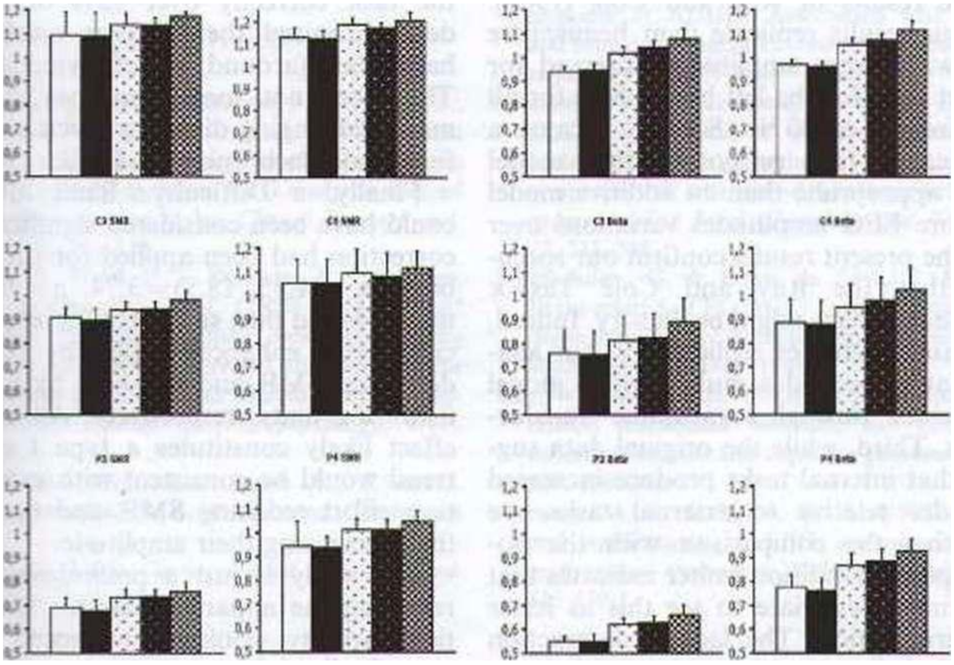

the data could be averaged across ATx-ulty levels for a second analysis ■wiving the control no-task-imposed in~~n~~ilion. There is little surprise that all Muncant effects of the first ANOVA are sat -resent after adding a third Task Task. 7*1(1.37. 13.7)=20.12, p<.0005; t-- i f< 1.55, 15.5) = 30.00. *p* < .0005: Hemi- ■rerre. fll, 10)= 179.41. /x.0005: Site, FI - 15.9)-522.98, *p* <.0005; with the miS significant interaction being that of H-— >phere by Site: F(1.72, 17.2) = 97.63, 7< U«»5. More important, as shown in fi pre 1. the results of this sccond analysis ir.caj.-d that the mean for the control no- -posed condition (1.067 (±0.036)) i cantlv differed from each of the _ r.c tasks, *F*\\, 10) = 24.I8, /;-.00l for MOT and F(l, 10) = 5.82, *p* - .036 for VSM

DISCUSSION

The main conclusion from this study is that the involvement in a task requiring attention in young adults causes a reduction in EEC spectral amplitude compared to a condition in which they simply wait for the upcoming trial. As indicated by the lack of interactions, this effect is essentially the same for all three bands across all six recording channels analyzed. Thus, in line with the general principle that brain activation tends to desynchronize neuronal activity, the results of our study reveal that the signature of increased attention is a reduction of alpha. SMR, and beta amplitudes. Therefore, the beta band effect turns out to be opposite to what is often interpreted as the reason why rcnormalizing low beta (increasing it) through neurofeedback is beneficial for

ADHD. This, however, does not mean that such target should be abandoned. Our data rather challenge the rationale underlying the success of the treatment.

Adding the neutral control condition brings an interesting complement to interpret the results of Ray and Cole (1985). First, our results replicate their hemisphere effect, with larger amplitudes observed for the right than for the left hemisphere for all bands from 8 to 20 Hz. Second, because a multiplicative (i.e., proportionality) model is more appropriate than an additive model to explore EEG amplitudes variations over space, the present results confirm our speculation that the Ray and Cole Task x Hemisphere effects might be illusory*. Indeed, their results were not replicated in our analyses that embedded a multiplicative model implemented through logarithmic transformations. Third, while the original data suggested that internal tasks produce increased amplitudes relative to external tasks, we found that the comparison with the no- task-imposed condition rather indicates that it is more appropriate to see this as lesser desynchronization. The lack of interaction of the Task factor with band or with topography leads us to consider that the MOT external task just requires more intense concentration and discredits the hypothesis of an extra motor inhibition during the VSM rejection task. Indeed, we did not find any sign of difference between tasks exclusive to the SMR band or to the central recording sites, which would have suggested a motor inhibition component. This interpretation is therefore consistent with a general decrease in EEG amplitude while performing a cognitive effort (i.e., steadily increasing desynchronization from no-task-imposed to VSM to MOT).

Because the influence of the cognitive effort required to perform the tasks is an important modulator of EEG patterns, the lack of effect regarding the Difficulty factor may seem surprising. Although some studies did find a significant effect of difficulty level on EEG patterns (e.g.. Sterman & Mann, 1995), Babiloni et al. (2004) illustrated that the prominent factor for EEG desynchronization is the nature of the cognitive effort rather than its difficulty. They observed that even their easiest task (i.e.. the retention of a single item) desynchronized the EEG spectra in the thcta and alpha bands. The results of our study revealed a similar effect, extended to low beta frequencies, in which performing the task correctly over 95% of the time desynchronized the EEG as much as the harder task (around 70% of correct answers). This does not mean, however, that still more challenging difficulty levels would not further desynchronize the EEG.

Finally, a Difficulty x Band interaction could have been considered significant if no correction had been applied for the number of tests, F(1.85, 18.5) = 3.74, /> = .046. The means would then show that increasing difficulty level enhanced alpha by 0.013 but decreased SMR and low beta by 0.006 and 0.007 log units, respectively. Although the effect likely constitutes a type I error, its trend would be consistent with extra attention effort reducing SMR and beta rather than increasing their amplitude.

Our study is just a preliminary step in resolving the apparent paradox that attention capacity would be enhanced through neurofeedback by increasing beta in children with ADHD and by decreasing it in adults without ADHD. Although our results only characterize the latter population, a reasonable doubt should be raised that the association between increasing 16 20 Hz. beta in children with ADHD and improving their attention capacity in daily life may not be as direct as previously suspected. As suggested earlier, one way to sustain increased beta is possibly to learn to tame an intrusive system that interferes with good management of attention capacities. According to that assumption, the lower part of the beta band should be considered as the idling rhythm of an internal system that would be over activated in ADHD. Such a system might be related to the profusion of distracting thoughts that intrude normal activity in the life of the child.

Identifying experimental conditions to test this hypothesis is a challenging task. Meanwhile, ongoing studies have been undertaken to explore whether comparable results could be obtained in children with and without ADHD. Should the present EEG data ra:;rrn replicate with children, a revised nicrpretation of the beneficial effect of -creasing beta through neurofeedback *c -Id become unavoidable.

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Visual Stimuli Generated by Biochemical Reactions Discrete Chaotic Dynamics as a Basis for Neurofeedback

Olga Grechko, MSc Vladimir CJontar. PhD

ABSTRACT. *Introduction.* In this article a novel methodology for a neurofeedback system is proposed. It is based on the visual stimuli generated by the distributed biochemical reactions discrete chaotic dynamics (BRDCD) of brain neurons. These visual stimuli take the form of symmetrical colored images known as mandalas.

Method. The proposed biofeedback system applies a BRDCD mathematical model to transform an on-line recording of EEG signals into a simulated time-series EEG and into computer generated series of mandala images. Thus, these images represent experimentally measured LEG and therefore reflect the subject's mental state.

Results. It will be shown that good qualitative similarity between simulated and experimental EEG was achieved. The examples of generating series of mandala images using experimental EEG will be demonstrated.

Conclusion. Based on Jung's theory of the healing power of the psychological phenomenon of mandala images, it is proposed that visual stimuli in the form of mandalas could facilitate fast and effective neurofeedback training, thereby providing a therapeutic effect.

KEYWORDS. Discrete chaotic dynamics, EEG, mandala symbolism, neurofeedback

INTRODUCTION

It is well known that visual stimuli and/or feedback play an important role in neurofeedback training processes (Thompson & Thompson. 2003). In this work, we present an innovative method for creating visual stimuli for use in neurofeedback. The proposed visual stimuli take the form of symmetrical colored images known as mandalas. According to Jung (1973), the majority of mandalas are circular images containing patterns in multiples of four in the form of a cross, a star, a square, and so on. although individual mandalas may present a variety of different motifs and patterns. Jung found that, as a psychological phenomenon, mandalas appear spontaneously in dreams, in certain states of conflict, and in cases of schizophrenia. He considered the mandala images painted by his patients to reflect their mental state in attempts at self-healing. In

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>. ok *Mandala Symbolism*, he stated, the mere attempt in this direction has a healing cffcct, but only is done spontaneously. Nothing be expected from, an artificial repetition deliberate imitation of such images" Si

A rote about a series of mandala painted by one of his patients over of years (Jung, 1973). The series Aith the spontaneous appearance of pictures in the patient's mind, patient had no artistic skills or pre- experience in painting, Jung encour- her to express her fantasies in He considered the appearance of -Liges as attempts by the subconscious its content by way of "individua- He tried to interpret the images but reveal his thoughts to the patient, the therapy advanced, the pictures reflecting changes in the patient's >iate and at the same time aiding rrrzress. In our opinion, this "therapy" an example of a pro-neurofeedback process.

images
a number
started

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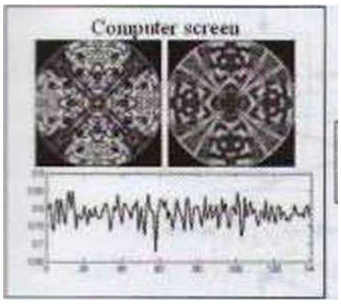
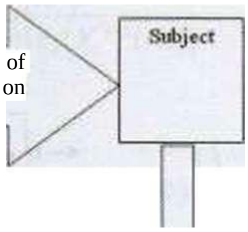
[illegible]

> findings reveal the rich potential of tor neurofeedback. But if we want them in practice, we are faced with the of how to replicate brain creativity in the form of images. Here, it seems that the general problem lies in constructing a theoretical model of brain functioning that will combine neuronal electrical activity (as observed by BEG) with the creative patterns, such as mandalas, that emerge from this activity. Such a theoretical model should connect the internal biochemical processes taking place in the brain neurons with macrocharactcristics reflecting the collective behavior of the brain neurons responsible for brain functioning. The biochemical reactions discrete chaotic dynamics (BRDCD) model visualizes brain processes in the form of creative images, as proposed in Gontar (1997, 2000, 2003, 2004).

Here, we intend to apply the BRDCD mathematical model for fitting, online in a neurofeedback loop, the measured EEG of an individual, denoted EEG^H, to BRDCD- generated images corresponding to a theoretical time series (EEG^1)- The simulated images will be directly related to the experimentally measured biological signals (EEG^H) of our test participant, which reflect the participant's mental state. Exploiting the proposed BRDCD mathematical model that formally connects and provides visualization of a participant's mental state with the BRDCD images, we can implemenl a neurofeedback system of visual stimuli (generated images.

" 3!ock diagram of the proposed neurofeedback method. *Note*. BRDCD ^ biochemical reactions rr-aotic dynamics.





as shown in Figure 1). In the light of the experience of Jung, we expect that BRDCD-based neurofeedback will provide fast and effective neurofeedback training.

BACKGROUND AND METHODOLOGY

According to BRDCD, each neuron can be simulated as a "biochemical reactor" that has the ability to exchange information with all the other neurons connected to it (Figure 2). By "information exchange," we mean another channel of interaction in addition to mass (via chemical reactions), charge, and energy exchange. In BRDCD. information exchange is formally taken into consideration by establishing the dependence of the model's parameters (rate constants) from the states of other neurons characterized by the concentrations of the chemical constituents within the neurons. The entire complex interconnected network operates according to some initial hypothesis about the mechanism of biochemical reactions in the individual neuron including information exchange between the neurons. The computations of such a mathematical model should correspond to the real distributions of the chemicals of the neuronal masses and the evolution of these distributions in time and space.

We assume that distributed chemical concentrations of neuronal networks are responsible for mental activity, including creativity. According to this basic premise, an artistic image would initially appear in the brain in the form of the distributed chemical concentrations of the neurons, and the output would then be a concrete pattern created by the individual. This pattern could be visualized by the proposed mathematical model (Gontar & Grechko, 2006b).

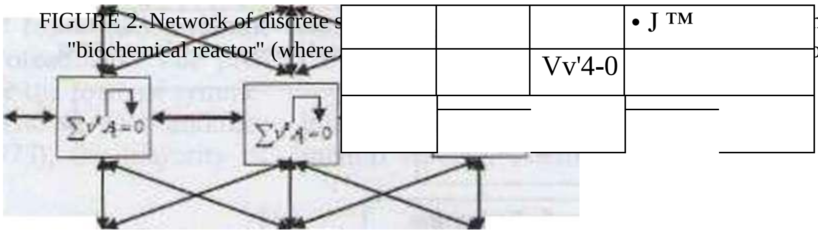


FIGURE 2. Network of discrete s neuron representing an individual "biochemical reactor" (where f stoichiometric coefficients).

BRDCD basic equations may be constructed for any mechanism involving transformations of the constituents of a system, which are expressed by a matrix of stoichiometric coefficients, and formally- including into the consideration information exchange between the constituents:

.v
]Ty% = 0,i=- 1.2,..., A^r, / = \ ,2_y,..*N* — *M* *i*=\
(1
)

In Equation 1. as shown in Figure 2 denote information exchange between neurons. According to chemical reactions discrete chaotic dynamics, in any transformechanism, a system's constituents ctn rc represented in discrete time t_q (</ - 0, L 2L .. Q) and discrete two-dimensional «cusje designated by the integer coordinates - R_P. R_s < DC, where *p* is the index «acs : ting the rows and *s* is the index denoting "rne . :.umns. For practical reasons, we limit j*.- consideration to a discrete square lattice of final size *R* x *R*. with coordinates

Rp- Rs = 1»2%*R-*

! - z basic equations of RRDC'D, when for a particular mechanism of transition of constituents and solved in time and space, provide a practically ted source of complex signals in the 4a-— ?f discrete time-series that encompass aux.^ and complex patterns in the form •f : »—dimensional images, including man- These results are used in the proposed >Iogy for a biofeedback system, us consider one of the simplest initial r - ."cscs about a possible mechanism of il transformations taking place in an Lai neuron. The hypothesis describes r.-.eraction between three chemical con- jests. -1, H, and C:

r i • m • n
' A A >

i i , I

i I------------- , ---------•
i i

(2)

where the solid arrows denote the chemical transformations of the constituents, the broken-line arrows denote information exchange between the constituents inside each cell of the lattice, and the finely dotted arrows denote information exchange between the constituents in a particular cell and the constituents in the closest neighboring cclls.

For this particular mechanism, a system of three nonlinear algebraic difference equations that describes the spatial-temporal dynamics of the neuronal network just presented can be derived from the basic equations of the BRDCD approach. For consistency of presentation, we repeat the description of the BRDCD mathematical model for mechanism (2) given in Gontar and Grechko (2006a, 2006b, 2007).

Y'ur R) = ——————— ——————— (3)

bn\(X'< '(r®))

(4)

' *$^{v) =}$ 1 + ■(«*)) + 'r®))

(5)

X?(R$_P$.R<) = *bniiX'^ir^faiX^ir®))*

1 + m(X'*r*^{1}(r^)) - n\ (r®))nz(Xj^4~^{1}(r®))

■ bere

(6)

^(■^/•"'(r®)) = k\ exp| — *2(X'r(r®))

(7)

= k$_2$ex p{

ř=i

^*iXl'*-^*R*^*R*^ + *f^P.X'rir®)*

with the initial and boundary conditions:

y'f(v u \ _ J x'*(rp< 1 < < R (inside the lattice)
\Kp>Kt) <y 0 Rf Ri < hRp>Rs > R (0Ulside the lattice) ['

where *X'*{Rp, R,)is* the concentration of the /th constituent that is calculated in each cell of the lattice with coordinates (*Rp,Rx)* and that characterizes the system's particular state at discrete time t_q (0=1,2 .... *Q);* TZl{t,; i,.r®) is a function of the concentrations of the system's constituents *X 'J (Rp , Rs)* calculated at a previous moment of discrete time and of the neighboring concentrations A'/'-1 (>'&); & is the total concentration of I he y'th main constituent: *k,<* is the rate constant for the /th reaction; % are empirical parameters that characterize the local information exchange taking place between the constituents inside the considered cell of the lattice: and are empirical parameters that characterize information exchange between the constituents in eight closest neighboring cells, including the cell under consideration (r — I. 2 .... 9), with coordinates denoted by:

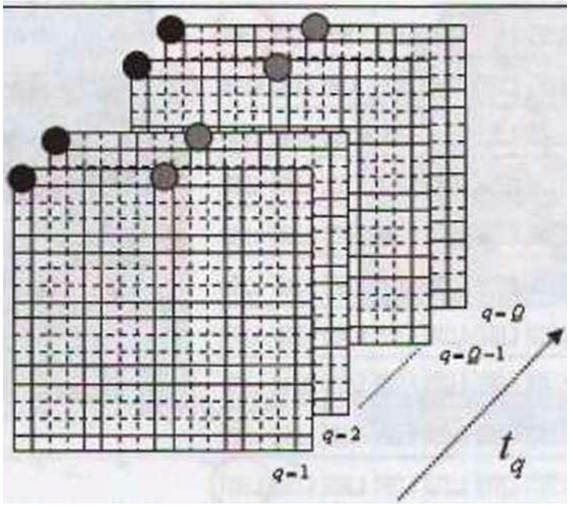
rS =[(,- I. Rs- \),(Rp-hRs),*
(A,-l.4v + l),(jtP.& 1),
(/?,,*,),(/?,,*,+ı),
{Rp+LRs-l)i
(Rp+\,Ry)y(Rp+\.Rs + l)].

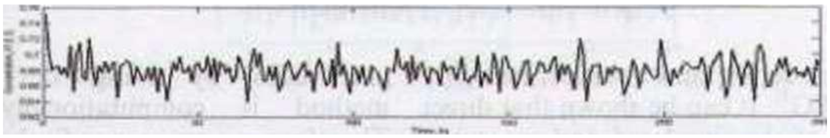
The mathematical model 3 to 5 has nine parameters *(b, kj, k2. zizJ-h-fik-h* that should be defined according to the type of image desired (symmetrical, nonsymmetrical, spiral, etc.). For any given set of parameters. Equations 3 to 5 generate a sequence of lattice-distributed concentrations (Figure 3) of the three chemical constituents and *X$(RP, Rx).* A schematic representation of this process is shown in Figure 3. Each cell in this lattice represents the concentration of a single chemical constituent (e.g.. *X['(RP.RS)* in an individual neuron). Therefore, if we pick, for example, the neuron in the upper left corner (marked by black circles in Figure 3a) and plot concentrations of the chosen constituent over time *f,r* we obtain a discrete time-series corresponding to the evolution of the concentrations within the individual neuron (Figure 3b).

The evolution of the entire neuronal network on the considered lattice can be visualized as a sequence of colored images. For this purpose, we assign to each concentration value (Figure 4b) a particular color from a color palette (Figure 4a). In this way. equal values are visualized with the same color (as designated, e.g.. with red circles in Figure 4c). Therefore, we obtain an image that represents the discrete space (lattice)-distributed concentrations of the constituent *X["(Rp. Rs)* for a given instant of time I^

Figure 5 presents some examples of images generated by the aforementioned mathematical model (Equations 7-9). As can be seen, these images meet the criteria for the mandalas described by Jung: they constitute circular patterns with symmetry of four crosses ("quaternity"). The mandala images presented in Figure 5 differ one from the other, and this difference in forms and colors depends on the parameters of the mathematical model. Tt is obvious that different sequences of images will correspond to different discrete time-scries (amplitude, frequency) generated by each cell of the lattice (neurons).

>=E 1 (a) Schematic representation of discrete time and space, where each cell (neuron) contains che- 5 concentrations that change with the discrete time t^. (b) Example of a discrete time-series representing *x*= evolution of the concentration of the chemical constituent within the individual neuron (marked by SDOCS), (c) Example of discrete time-series from another neuron (indicated by gray spots).





(b)

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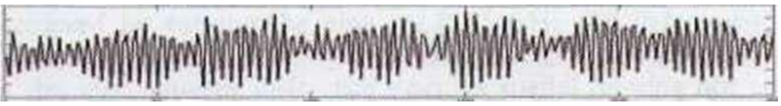

No** let us apply linear superposition >n 10) for these discrete lime series m «e«Liin an integrated signal representing Ac t^poral dynamics of the whole neuro- SZL TC^{R}VSORK under consideration, where JCS srpirically defined parameters:

EEG^{T}- ^^(R®)

$i = \backslash, 2, \ldots RxR$ (10)

call this integrated signal, which raieco the temporal dynamics of the whole JBSX-C -distributed neuronal network under - *r*.juration, a "simulated EEG signal" or EEC- : :gure 6a and b presents two exam- integrated EEG^{1} signal obtained for 15 and for two different sets of parameters (b, k,. k_2A\, ^z^h-PhJii-Pi)* *Equations 3 to 5.*

To combine signals from two (or more) local neuronal networks, wc propose to apply superposition 10 of already-integrated signals resulting from different neuronal networks. This procedure will constitute a more realistic approach to the brain functioning, where different parts of the brain (presented by local neuronal networks) operate in parallel to contribute to the measured integrated EEG^{L} and should therefore be taken into account. Figure 6c presents an example of an integrated EEG^{r} signal for two different neuronal networks.

To apply the aforementioned methodology, one can establish a correlation between EEG^{1}, that is. an EEG simulated by a

BRDCD time-series, and an experimentally measured F.F.G'. It can be shown that direct comparison of the simulated and measured time series in terms of their synchronized amplitudes by using the least-squarci method is computationally ineffective Therefore, we propose to lit the experiment data to our model in the frequency domain

FIGURE 4. Encoding of the calculated concentration of one of the neuron's constituents by means of a color palette (a). Equal values shown in (b) are encoded with the same color, as for example, values marked by red circles (c).

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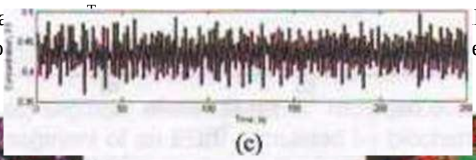
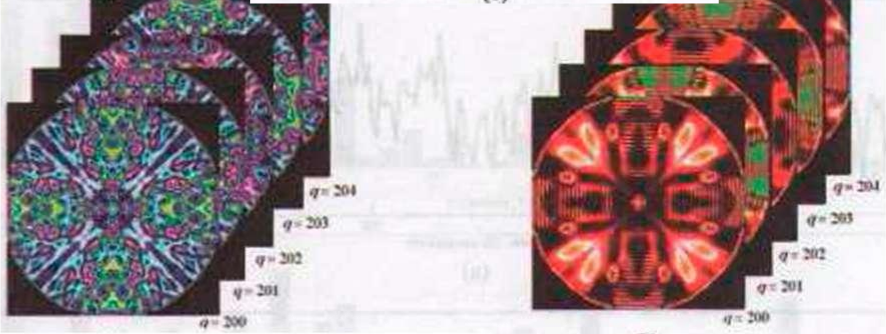
FIGURE 5. Examples of mandala images generated by biochemical reactions discrete chaotic dynamic BRDCD.

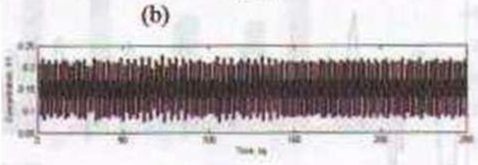
The fitting is achieved by varying the nine parameters of the model (Equations 3-5) so **i> to** minimize the least-squares difference **between** the spectrum of the experimental EEG^{f} and that of the theoretical EEG^{T}.

: -3URE 6. (a, b) Examples of simula la images. -r> Example of combined signal coming from two different gro e presented in Figure 6a and 6b.





(a)



RESULTS

lr. this section, we present experimental "cation of our theoretical approach. Wc applied the aforementioned methodology v EEG^{C} signals with the aim of generating ± corresponding series of images. For "rc-rding the EEG^{L}, we used a custom-built EEG amplifier with four channels and a s^r.pling rate of 250 samples per second. Dis- rv. ^ible golden electrodes were used in the ¡aperiment. EEG^{1} signals were obtained ^zg single channel assessment (referential a^r-iagc with reference to ear lobes). The seconding was accomplished with a gain of : • \. providing us with a full-scale 1-mV T^ii-to-pcak. The filters were set at low pass (LP) 125 Hz (24db/octavc) and high pass (HP) 0.16Hz (12 db/oetave). We applied neither digital filtering nor artifacts removal. Our participant was healthy 29-year-old man with no known medical problems.

FIGURE 7. (a) One-s (250 samples) segment of an experimental raw EEG^{C} recorded over Pz with eyes open. (b) One-s (250 samples) segment of an EEG simulated by biochemical reactions discrete chaotic dynamics. (c) Examples of 6 (q= 1. 50. 100. 150. 200. 250) of 250 mandala images corresponding to the simulated EEG^{t}.

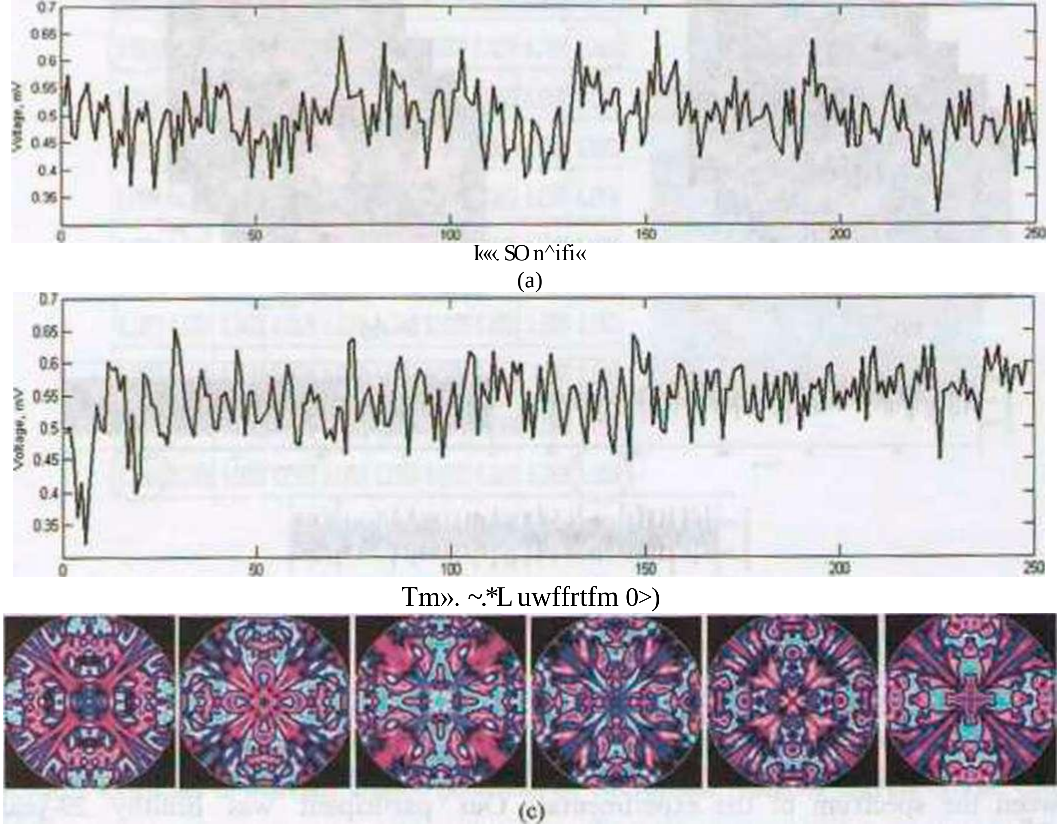


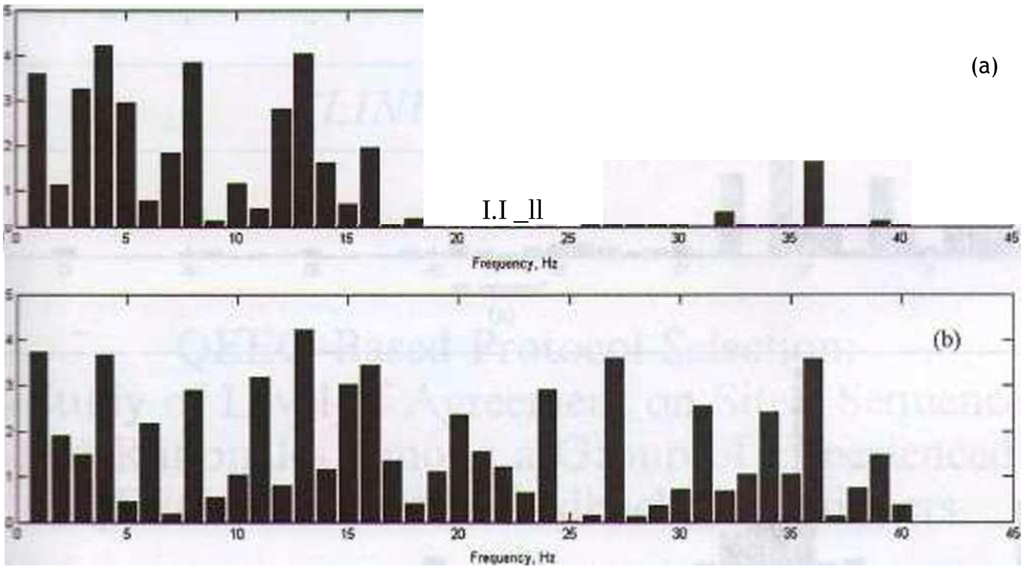
Figure 7 (upper panel) shows a 1 -s segment of a raw EEG^{e} recorded over Pz with the participant's eyes open (upper part). The central panel of the figure shows the integrated time-series generated by the BRDC'D mathematical model, which represents the temporal dynamics of 10.000 neurons (250 iterations corresponding to 250 samples of the 1-s EEG^{l} segment). The lower panel of Figure 7 presents a representative sample of 6 of the 250 mandala images corresponding to the simulated signal. To analyze correspondence of the EEG^{R} and EEG^{e} signals we compared these two segments by computing their bandwidth spectra (Figure 8). Here we can clearly see the qualitative correspondence of these two signals within the 1^0 Hz frequency domain (we have omitted high frequencies on a plot [Figures 8 and 10], but they were included into consideration for EEG spectral analyses).

Figure 9a shows a 1-s segment of a raw EEG recorded over Cz with the participant's eyes closed. Figure 9b shows the integrated time-series generated by the BRDCD mathematical model, which represents the temporal dynamics of 10,000 neurons (250 iterations corresponding to 250 samples of the 1-s EEG^{e} segment). Figure 9c presents six mandala images chosen arbitrarily and corresponding to six r_q values {q— 1. 50, 100, 150, 200, 250) of the signal in Figure 9b. Again, the qualitative resemblance between EEG$^{1'}$ and EEG^{1} can be seen and was confirmed by the corresponding spectra (Figure 10).

CONCLUSIONS

The proposed method for neurofcedbac provides a direct connection between exper mental EEG^{R} signals and the states < spatially distributed neuronal networks the form of colored symmetrical images mandalas. We propose to use the EEC related mandalas as visual stimuli in neurofeedback training process. In view the belief of Jung -that mandala imag< being generated involuntarily, may have therapeutic effect on a person's menf health—we predict that stimuli of tl kind could provide fast and effective trainir The mandalas generated involuntar according to the mental state of our t<

=GURE 8. (a) Bandwidths of the experimental EEG^e shown in (a), (b) Bandwidths of the EEG' simulated by r :<:-•= Tvcal reactions discrete chaotic dynamics, shown In (b).



^{R} 3 ,=E 9. (a) One-s (250 samples) segment of the raw EEG^e recorded over Cz with the participant's eyes b) One-s (250 samples) segment of an EEG^1 simulated by biochemical reactions discrete chaotic >. (c) Example of 6 (q 1, 50.100,150, 200, 250) of 250 mandala images corresponding to the simu- EEG^T.

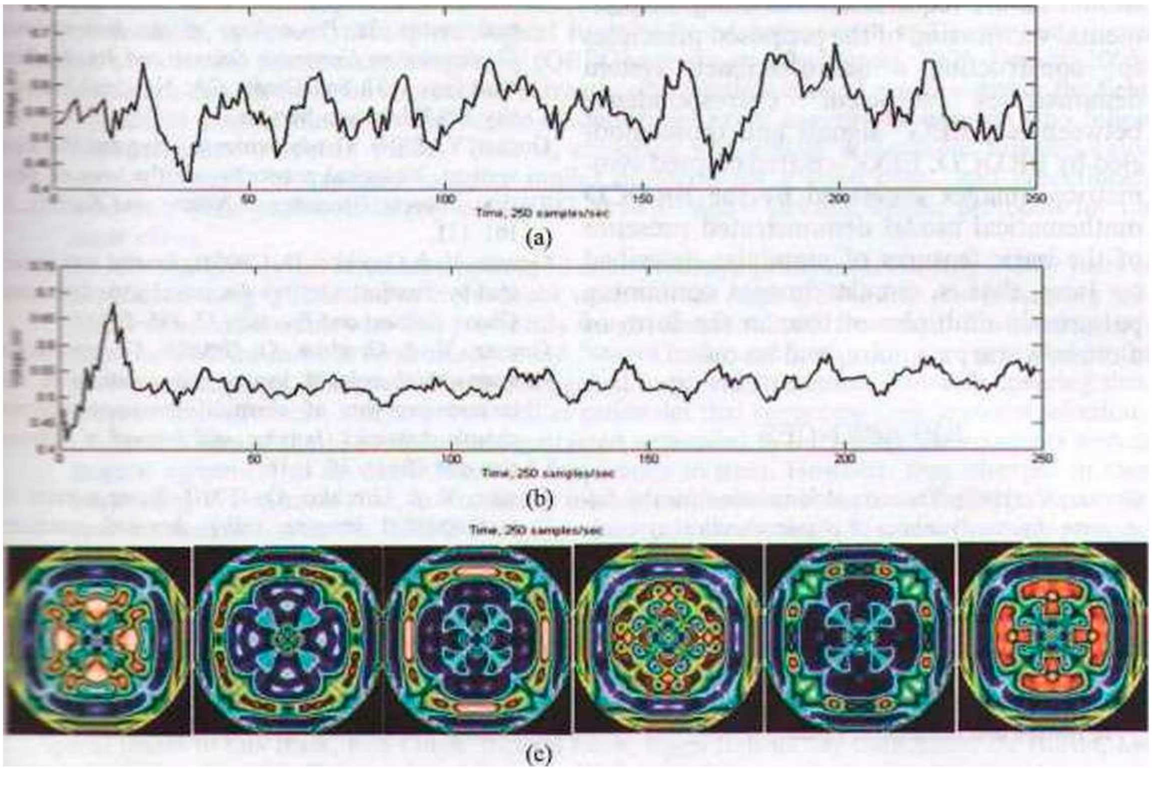
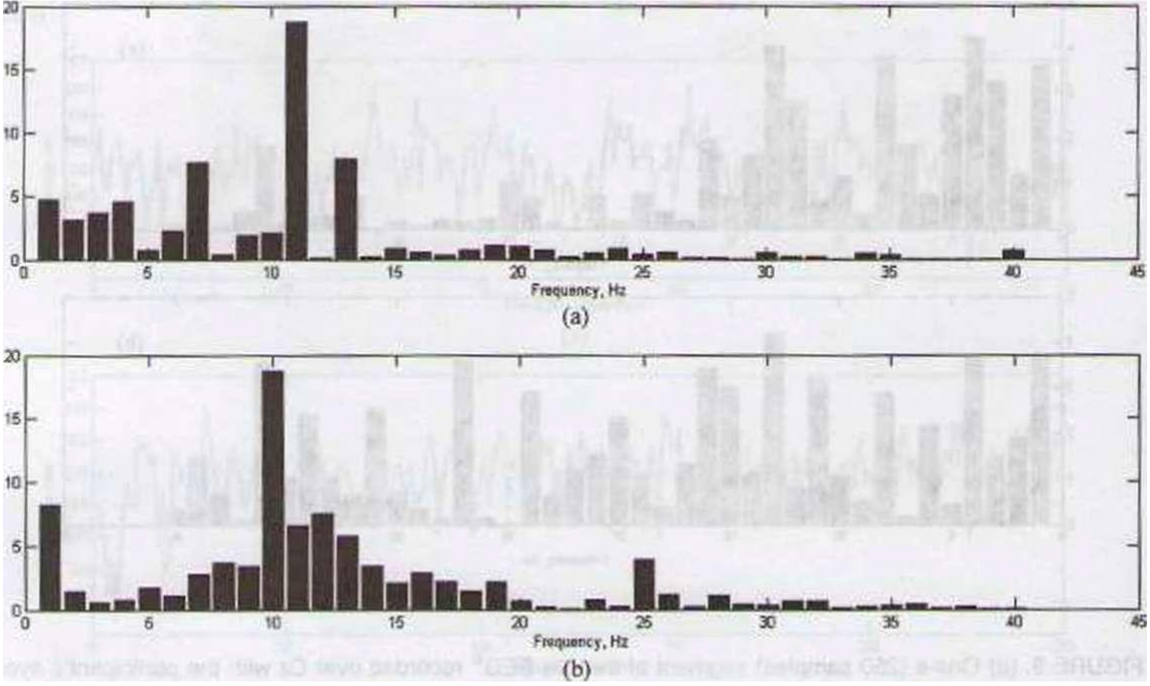


FIGURE 10. (a) Bandwidths of experimental EEG^e. (b) Bandwidths of EEG^1 simulated by biochemical reactions discrete chaotic dynamics.



participant—as presented by his EEG- should fit the requirements of Jung. Experimental verification of the proposed principles for constructing a neurofeedback system demonstrates sufficient correspondence between real EEG^F signals and those modeled by BRDCD. EEG -related colored symmetrical images generated by the BRDCD mathematical model demonstrated presence of the basic features of mandalas described by Jung, that is, circular images containing patterns in multiples of four in the form of a cross, a star, a square, and so on.

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Conclusions. Although further research will have to document rhe efficacy of the various protocols recommended by the experienced QEliG-based practitioners surveyed for this study, it can be assumed that these practitioners are finding some consistent success using them in their practices. Therefore, the primary implication of this study appears to he that as long as appropriate treatment sites and frequencies are addressed lor a given client, competently applied neurofeedback seems to be robust enough to tolerate a relatively wide diversity in specific protocol configurations.

KEYWORDS. Neurofeedback, QEEG, protocol selection

INTRODUCTION

The evolution of neurofeedback clinical practice has involved the emergence of several different theoretical and application orientations. from the use of standard research protocols for specific disorders, such as the Peniston Protocol for alcoholism and Post-Traumatic Stress Disorder (Peniston & Kulkosky, 1989, 1990, 1991) and the frontal alpha asymmetry protocol for depression (Baehr. Rosenfeld, & Bachr. 2001). to the symptom/neurophysiological function based approach credited to Sigfricd and Sue Othmer (Othmer, Othmer & Kaiser, 1999). More recently, there has been increasing advocacy and use of quantitative electroencephalography (QEEG) to help determine neurofeedback protocols (Hammond, 2006: Kaiser, 2006). However, very little is known about general clinical practices among neurofeedback practitioners who use QEEG-based treatment protocols. We were curious to know how much uniformity exists in neurofeedback protocols that are derived in part from pre-treatment QEEG data. That is, given the same client information, presenting symptoms, and QEEG record, do most experienced neurofeeedback providers using QEEG-based protocols design a protocol containing common features in terms of frequencies, sites, sequence of addressing each site, inhibit/reinforce, and so on? To date, no studies have been published addressing this question or describing the general range of clinical practices in QEEG-based neurofeedback. Nor. for that matter, has any investigation explored lhe level of consistency among neurofeedback providers who use a symptom/function-based approach. To address the question of similarity in QEEG- based neurofeedback protocol selection. 2 small survey investigation was initiated tc determine how much commonality actually exists among neurofeedback practitioner: experienced in using QEEG to help guidt their protocol development.

METHODS

Thirteen International Society for Neurofeedback and Research members known b; the authors to be experienced clinician who use QEEG-based neurofeedback wer invited to participate in this descriptiv research project. The sample was nonrar dom but stratified to include and contra« QEEG-based neurofeedback practitionei with 5 to 10 years of experience with pract tioners with 20 +years of experience. Te individuals responded to the survey reques Five of the respondents had more than 2 years in QEEG and neurofeedback, and th other 5 respondents had between 5 and 1 years. All were mailed a compact disc coi taining the QEEG data, background info mation and presenting problems of a anonymous female client who had previous sought neurofeedback treatment. The QEE data was edited in both Neurorepo (NREP) and Neuroguide (NG), and bo edits were provided to the survey partic pants. Each respondent was asked to outlii a treatment protocol based on the QEE and brief client summary data providi and to indicate the sites, sequences, ai rationale that supported his or her pr tocol recommendations. Respondents we encouraged to use the International 10/

system (Jasper, 1958), which allows standardized placements of electrodes when recording EEG brain wave activity (Bocker, • an Avermaetc, & van den Berg Lennson, .994). All respondents received the following summary of client background and symptom information and QEEG topographical data, edited in both NG and NREP.

Client Background and Symptom Data

> *The client whose QEEG record you have has already been treated in the University of North Texas Neuro therapy Lab. She is a 57-year-old Caucasian female. Her presenting symptoms were: stress issues, depression, lack of motivation, pain, sore muscles, and sleep problems. She was on the following medications at the time of the QEEG: Fosomax-Cal- cium (herbal supplement) 1 pill I time per week for osteoarthritis. The dale of the QEEG was 12/5/05 (Monday). On 12/3/05, she had had a glass of wine.*

Client QEEG Topographical Data

Sec Figures 1 through 7 for the client QEEG topographic data.

RESULTS

All survey respondents agreed on the specific 10 to 20 sites to be treated. However, participants diverged rather significantly v. hen it came to sequences, rationales, and nhibits versus reinforces in their protocol recommendations. There was as much diver- sily in recommendations within the more experienced subgroup of respondents (all of »hom are recognized leaders/pioneers in :he field) as there was in the subgroup of professionals with fewer years of experience with QEEG. (All protocols recommended aiong with rationales are presented in table form in the appendix.) The following is a nummary of each survey respondent's individual protocol recommendations and comments regarding their selection rationales.

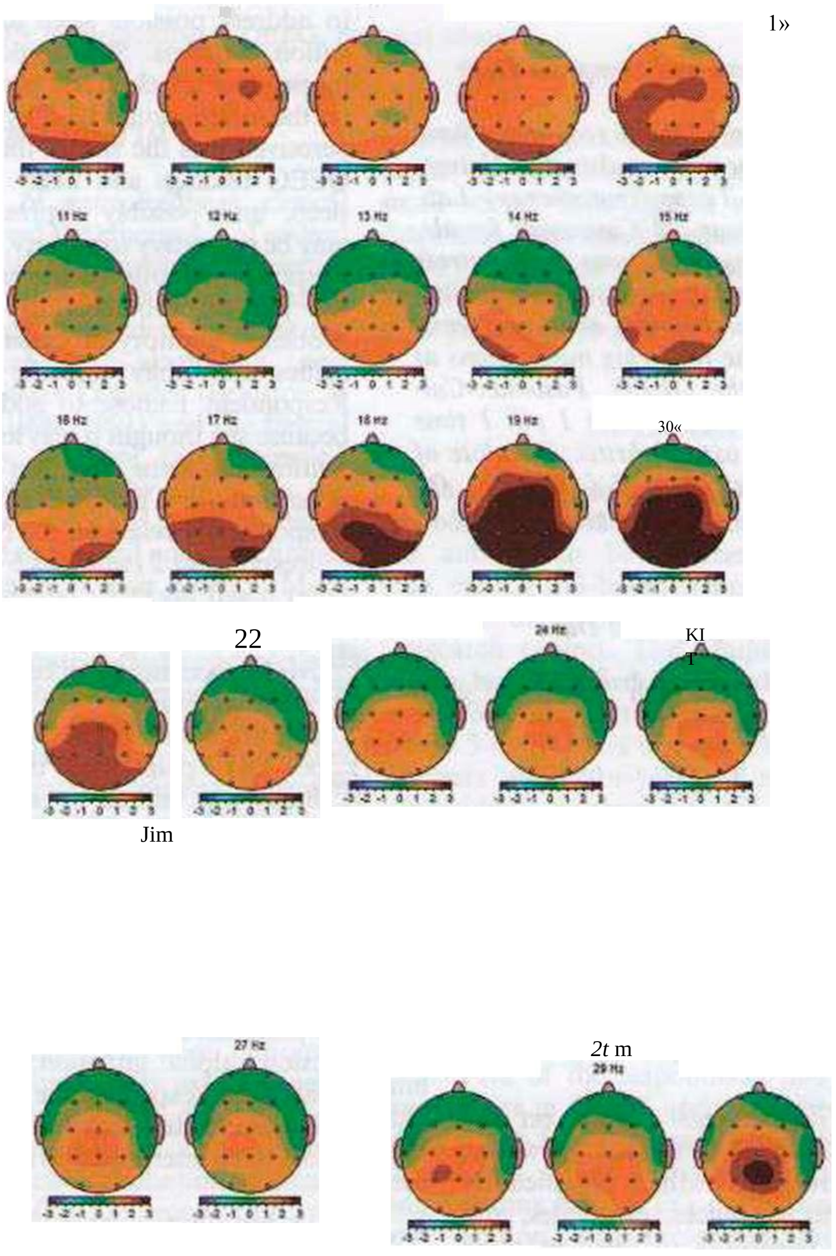
Respondents' Protocol Selections and Rationales

Respondent 1 (who has 5 years of experience) stated that she would start with FZ (a frontal vertex electrode placement site based on the international 10-20 system, Jasper, 1958) to "get frontal lobes working" first and to address possible sleep and lack of motivation concerns. She would then go to PZ (parietal vertex electrode placement site based on the international 10 20 system), which she perceived was the site of the most significant QEEG findings and likely related to stress, sleep, and possibly depression (and which may be secondary to anxiety, sleep, and stress). Respondent 1 offered the same rationale for left parietal protocols to address memory problems, auditory processing, or social difficulties that may underlie other conccrns. Respondent I chose to address this site last because she thought it was least related to presenting problems and less significant than other findings in the QEEG topographic maps. Respondent 1 relied on the NREP maps.

Respondent 2 (who has 6 — years of experience) based his input largely on NREP Ncuroelectrieal Imaging (NEi) data showing a relative hypoconnectivity between F7 and P5 and some excessive power over the parietals in relative power maps (NREP and NG). Respondent 2 pointed out that the eyes-closed condition was tainted by a driven reference. This phenomenon may also be referred to as intrusion, alpha intrusion, or false frontal alpha. Several experts in the field (Rob Coben, Bill Hudspeth, and Jack Johnstone) agree with the following interpretation and nomenclature:

> It is not an artifact. It is a real signal. There is always activity ai the reference electrode and the measurement is the difference between this and the active site. If the activity generated at or near the reference is greater than the activity at the "active" site, then it will show difference due to the activity at the reference. This most often occurs with alpha activity in the temporal cortex, but other frequencies, references etc. could cause similar distortions. (R. Coben, personal communication, October 16, 2008).

FIGURE 1. Neuroguide Z scored absolute power map eyes closed.



Respondent 2 noted that the driven reference collapsed the NEI frontally in theta and alpha and to some degree in beta. This artifact led to hypercoherence in the alpha band and threw off other readings as well. This respondent viewed the eyes-closed data (both trials) as uninterpretable and would want another recording done or remontaging at the least (but felt this would not eliminate the problem).

Respondent 3 (who has 20 +years of experience) recommended Sensory Motor Rhythm (SMR) training at C3 and C4 for mood stabilization, improved sleep, and perhaps to help with muscle pain. He then would move to PZ to decrease anxiety and increase relaxation, with both eyes-open and eyes-closed training. Respondent 3 suggested next working at FZ to increase alertness. This last protocol was designed to decrease depression, increase motivation, and reinforce executive functioning such as decision-making and planning strategies.

FIGURE 2. Neuroguide Z scoreo absolute power map eyes open.

Iltt 2Q 3 HZ «MX SRX

£> ^ Q

J1^^?^?1^ -s^TTTT^

• « Im MX I Hi tOMi

-j;-toirJ >jIoi2i -1313 13)4 : > i < ; tta-itwi

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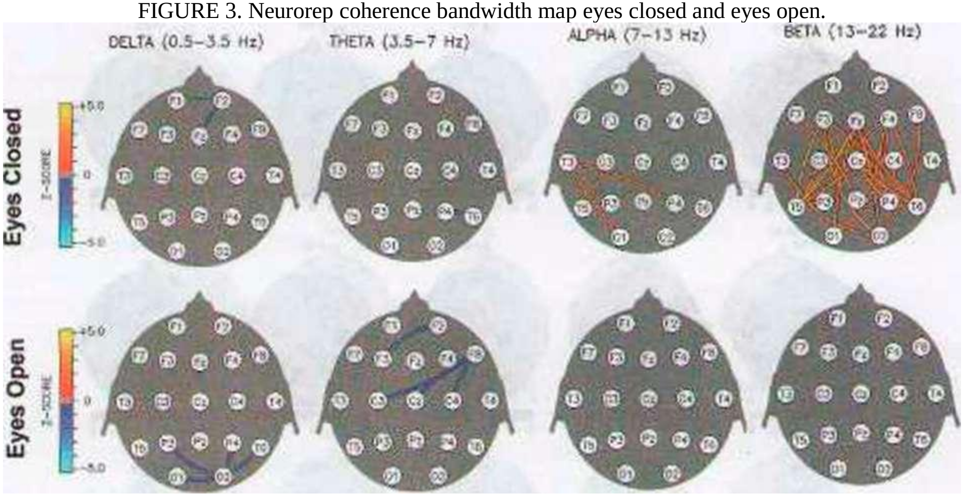
•I 4 -1 4 1 3 J 4 C I I I : i -3 3.10 1 3 1 » 3 • 0 • 3 » ■> -3 0 1 3 J

Respondent 4 (who has 10 years of experience) would seek clinician/patient agreement as to which symptoms seemed most important to address first. He stated he would recommend starting with sleep because studies indicate that pain interferes with sleep

He would then proceed frontally because that was where most of the imbalances were located. Respondent 4 would reward (reinforce) slow wave activity (1-7 Hz) as indicated by the maps, and he reasoned that rewarding slower wave activity should help and, in turn, sleep disturbances increase pain, to improve deeper sleep. Respondent 4

FIGURE 3. Neurorep coherence bandwidth map eyes closed and eyes open.

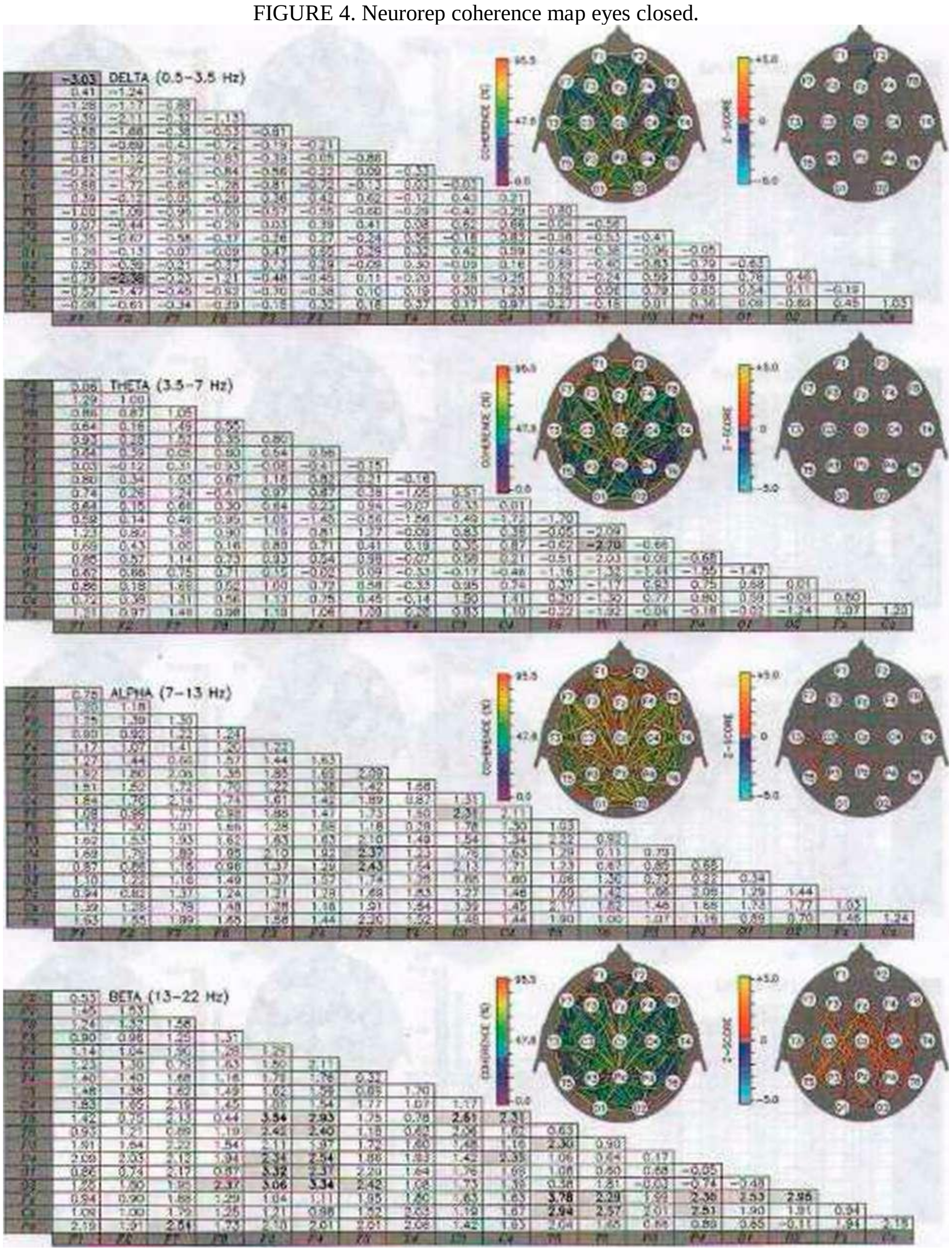


hypothesized that increasing most band- widths frontally should help with improving pain symptoms. However, Respondent 4 narrowed his approach to coincide with QEEG findings. Respondent 4 continued to stay with the frontal lobes because it is implicated with depression. He also stated the maps showed a lack of relative power frontally in the beta bands. By activating the frontal areas. Respondent 4 hoped "to get this person going." If not, he would start looking at other options and considered this an interactive process, with all of these recommendations just seen as starting places. Respondent 4 went through the literature regarding osteoarthritis, pain, sleep, and EEG to determine what to look for with this patient's profile. He weighed the relative power results more heavily than the absolute power results. Finally, he combined the literature, symptoms. and QEEG results to come up with his protocols. If going through the above protocols produced no success, he would then train coherence based on NX-Link first, then NG and NREP.

Respondent 5 (who has 20 +years of experience) provided site-by-site rationales, which included the following: Decrease 2 to 7 Hz and increase 15 to 18 Hz at FP02 to relieve depression. His rationale w^{r}as that this is the best protocol his team has found for treating depression and is not based on the QEEG. The rest of his suggestions were all based on his iModular Activation Coherence model of brain function and neurofeedback training: decrease 1 Hz at Fl plus F2 tc decrease ADHD symptoms, decrease 1 H; at F3 plus F4 to improve motor plannint on the right and motor planning on the left decrease 1 Hz at T3 plus T4 to improv. memory, decrease 1 Hz at C3 plus C4 t< improve sensory motor integration on th right and handwriting and sensory moto integration on the left, decrease 1 Hz at T plus T6 to improve verbal understands and emotional understanding, decreas 1 Hz at Ol plus 02 to improve visual proccf sing, decrease I Hz at P3 plus P4 to improv cognitive processing of language and spatic temporal information and math skill decrease 21 to 30 Hz and increase 10 Hz « PZ plus P4 to decrease anxiety and irritabi ity and to improve cognitive processir generally and cognitive processing of spatii temporal information, and increase cohe ence of delta at P3/02 to integrate cogniti- processing of language and vision to the le The reason for delaying the anxiety protoc until number 8 was that his experience h been that if the patient's cognitive difficulti arc improved, treatment for anxiety will more effective.

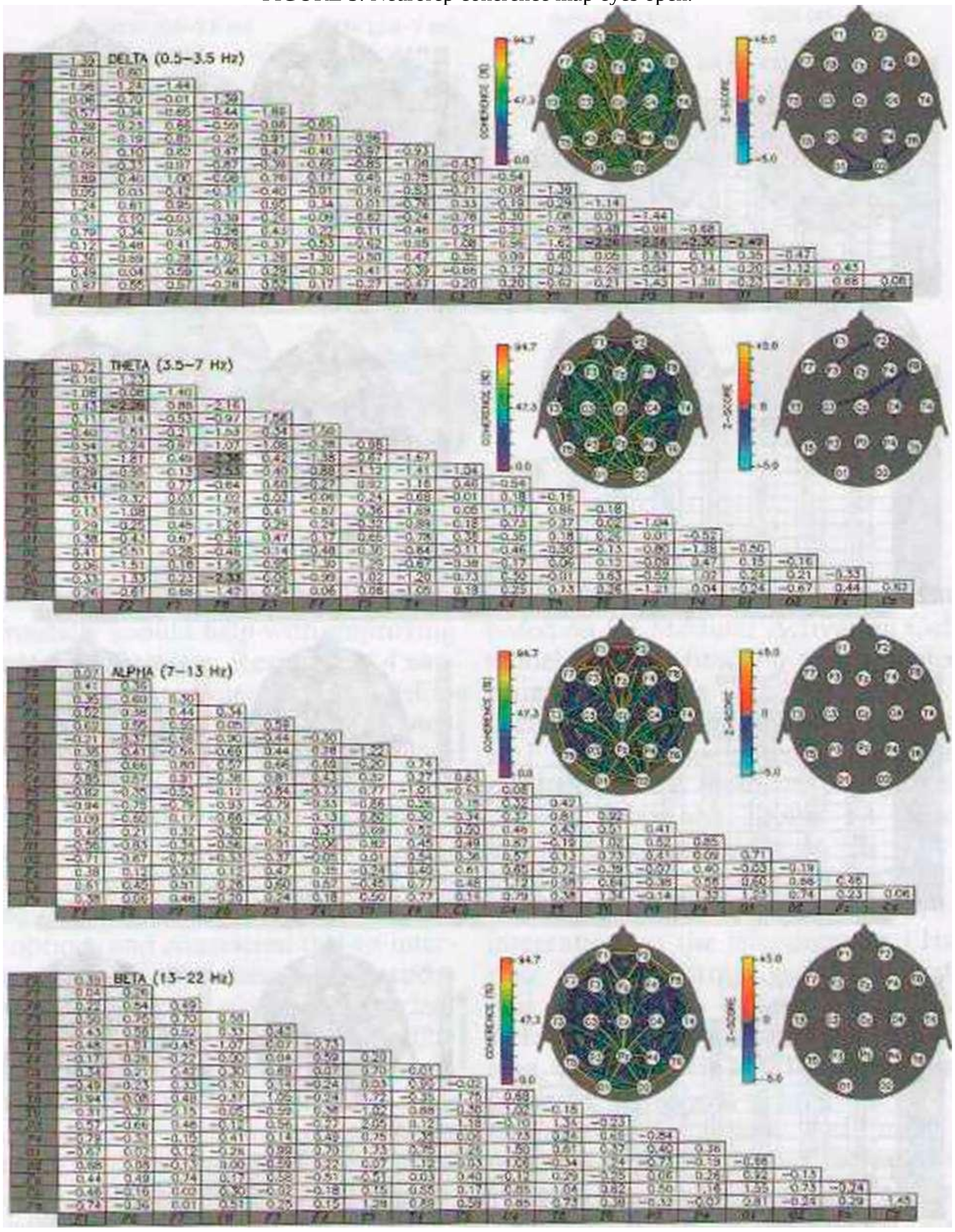
Respondent 6 (who has 8 years experience) utilizes protocols that rcqu

FIGURE 4. Neurorep coherence map eyes closed.



BrainMaster equipment with the "Sweet Spot" parameters (Black & Bodenhamer- Davis, 2003; McGee, 2002; or the old Neurocybernetics equipment), because "each system is set-up with unique filtering and timing of feedback which optimizes treatment efficacy," The BrainMaster Sweet Spot manual describes the sweet spot method as an approach where subtle adjustments in training parameters can be set before treatment and finely adjusted during training sessions to fine-tune parameters while treatment is in progress. Respondent 6 relies heavily on raw wave data and observed the driven reference artifact of alpha activity in the QEEG.

FIGURE 5. Neurorep coherence map eyes open.



Respondent 6 would begin with eyes open training and see how her client could handle it. "The client's excesses are exacerbated in the eyes open condition, which may make it more difficult for her to begin there." But Respondent 6 stated she would be awire of this and move to eyes-closed training if she was not seeing the shifts she w ould expect to see. Respondent 6 stated her training would be done using bipolar hook-ups and using the Brain Master with the Sweet Spot pai meters. She considers this approach qu dynamic and treatment may include seve: placements and reward (reinforce) frequt cies that change during the session. "The (ent is not left alone as the therapist watching for changes and applying a t\ of desensitization during the therapei conversation (e.g.. making sure tl anxiety-producing issues are discussed

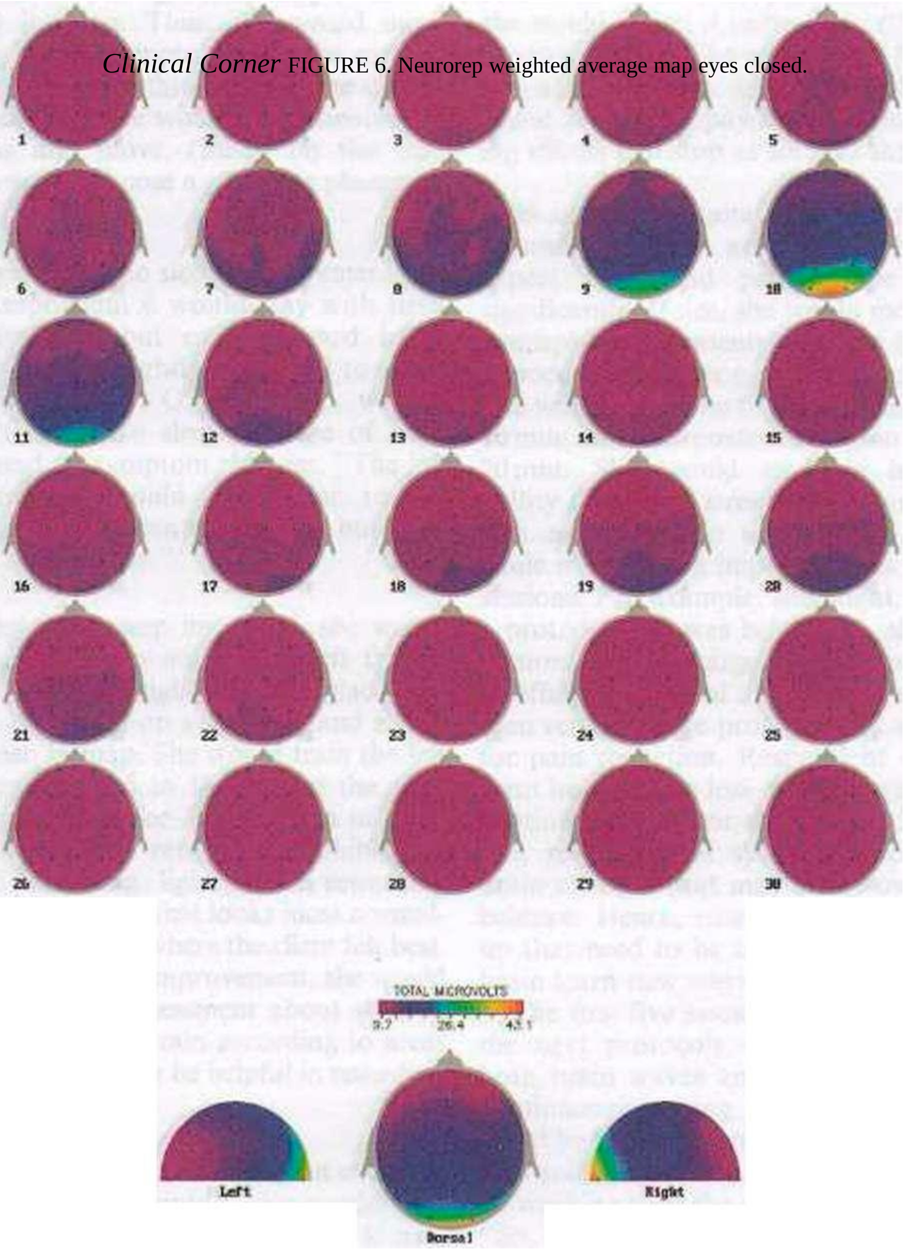
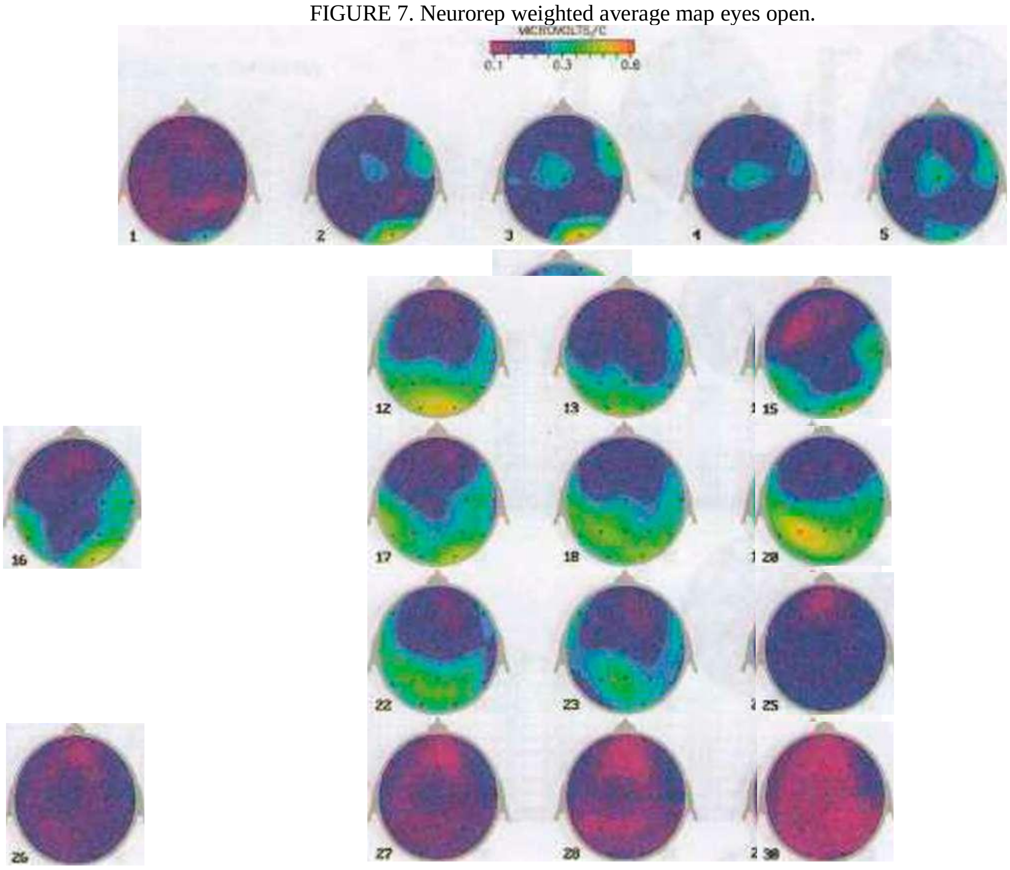


FIGURE 6. Neurorep weighted average map eyes closed.

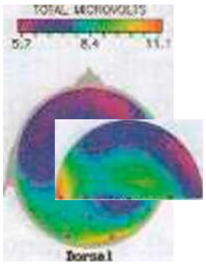
conjunction with the feedback)." Respondent 6 outlined the following protocols and rationales session by session:

First session. Respondent 6 would first work C5-C6 and C1-C2. She would experiment with 2-7 Hz or 2-13 Hz and 20-30 Hz or 14-30 Hz inhibits and experiment with the reward, which is likely in the S 11 Hz range (map power, amplitude, and peak frequencies) but should be tweaked up or down to find what feels best for client and looks best in EECi (i.e.. more normal). "Sweet Spot reward range could conceivably end up

FIGURE 7. Neurorep weighted average map eyes open.



Left



between 0-3 Hz and 15-18 Hz depending on connectivity, coherence, phase, asymmetry, and amplitude *relationships* that are not well documented in the maps. Inhibit lightly and reward generously for approximately 15 minutes at each site, but may be less— if 2 7/2 13 Hz rises sharply after 5 to 10 minutes, stop training at that site." Respondent 6 expected her client to feel better in the first session. She expected to se< improved relaxation and calmness (basec on subjective ratings) in conjunction wit! improved alertness (ratings here also) anc a significant reduction in degree of pain

"The EEG typically softens and the spectral appears even (e.g., no big peaks)." If her client experienced nothing, she would assume *she* was not at the right frequency or not at •.he right location. Thus, she would move according to the symptoms and the map. If •Jiat happened with this client at the central sulcus locations, she would pay attention to symptoms and move. (Based on the map only, she would choose a posterior placement such as P3-P4.)

Second session. If no sleep improvement was noted. Respondent 6 would stay with first- session protocol but either reward lower **e.g.,** sleeping too lightly) or add 3 to 9 min of left frontal (e.g., C5-AF3; e.g., waking and can t return to sleep because of busy mind) based on symptom changes. "The left frontal reward should be similar to the reward across the central sulcus, but may be up to 2 Hz higher."

Third session. If sleep improved, she would begin to target pain and utilize left frontal e g.. C5-AF3) plus right posterior placement iz g.. C6-P4) based on symptoms and asymmetries seen in map. She would train the left frontal region for 5 to lOmin and the right rv >terior quadrant for 20 to 25min utilizing S^eet Spot reward ranges and inhibit frequencies, inhibiting lightly and rewarding ¿enerously based on what looks most normalized in the brain and where the client felt best. If there was no sleep improvement, she would act more detailed assessment about what is ¿¡>turbing sleep and train according to areas of the brain deemed to be helpful in remediating this concern.

Fourth session. If her client had an excellent roponse to prior training, she would stay close to prior sites and frequencies. If not, she would move to AF3-AF4 sites in combination with CP5-CP4 based on symptoms _nd power and amplitude maps. She would the inhibit ranges that felt and looked ^sst (e.g.. more normal) during the first session and reward the frontal locations slightly lower (e.g., 1/2; to 2 Hz. lower) than the Sweet Spot at the central sulcus, and at pos- :enor locations, 1-4 Hz lower than Sweet Spot. She would expect to make adjustments during the sessions and would not «xpect the reward frequency to be the same during this session as it was in the prior sessions, though she would expect it to be close. ("It typically drops slightly.") She would train frontal sites for aboul lOmin and posterior sites for about 20 min but pay attention to overtraining effects and stop as soon as they are seen.

Fifth session. The site she would train would depend on goal attainment. She would expect sleep and pain to be improved significantly. If not, she would move to right hemisphere placements based on NREP NE1 hypoconnectivity (e.g., C6 AF4 and C6-P4). She would train the frontal region for about 10 min and the posterior region for aboul 20 min. She would evaluate her client's ability to handle stress, mood, and motivation and begin to target these symptoms while maintaining improvements from prior sessions. For example, she might train using a protocol that was helpful for sleep at one session and then target new symptoms using a different protocol at the next session, and then return to the protocol that was helpful for pain reduction. Respondent 6 wouldn't want her client to lose any gains; she "would continue to monitor changes, understanding that resolution of symptoms correlates to brain changes that may affect overall brain balance. Hence, new symptoms could crop up that need to be targeted as areas of the brain leani new ways of functioning."

The first five sessions would be critical in the next protocols chosen. Assessment of both brain waves and symptoms would be continuously taking place so that decisions could be made and training tweaked for optimal goal attainment. She did not expect to be working with the same map at this point. "So. Sweet Spot reward frequencies may be very different than during the first session (typically lower)." Respondent 6 used both NG and NREP to determine her protocols.

Respondent 7 (who had 20 +years of experience) developed some of his own "tri-angulated" electrode site placements based on the 10 10 system but used 10 20 site references to decrease confusion. For example. LFT referred to "left frontal triangle," a point equidistant from F7. FP1, and F3. LPT referred to "left posterior triangle." a point equidistant from T5. P3, and 01. Respondent 7 believed that activating all three sites enables them to be treated simultaneously. Respondent 7 would reduce 5- 15 Hz at OI *& 02* (2 channel), reduce alpha cohcrence at LFT RPT, reduce 17-21 Hz at F3 & RPT (2 channel), reduce alpha coherence at RFT LFT. reduce 13-21 Hz at

F4 & LPT (2 channel), reduce alpha coherence at F3 CZ/C4, reduce alpha coherence at T5 CZ/C4. He would do the entire sequence (1 through 7) completely, repeat the sequence Five times, and then remap before he would continue to work.

Respondent 7 said the aspects of training that were most important to him were to choose the highest *z* scores for potential treatment sites. Beyond that, he just wanted to alternate coherence and amplitude training and "move around the brain" in treatment rather than focus on a particular location. He believed that "this produces greater and faster overall changes on/in the brain, although slower change at a particular site." Respondent 7 said he and a longtime colleague debated whether to train power (amplitude) first or whether to train coherence first. He eventually came to believe that overall activation might be improved by moving around rather than focusing on a particular location for several consecutive sessions. So the three aspects of his choices were (a) highest *z* scores provide potential sites, (b) alternate amplitude and coherence/ phase, and (c) provide a sequence that moves around the brain rather than focus on one location.

Respondent 8 (who has 8 years of experience) generally uses primarily slow and fast wave inhibit protocols, seldom reinforces. If QEEG and symptoms indicate, he likes to work frontal first, moving next to the motor strip/central areas, and then into the posterior areas of the brain. Tn this case, though, he felt it was necessary to try to help bring about calming by reducing the parietal high beta, and then he would move into his usual course of protocol sequencing. Respondent 8 uses a 20 30 Hz inhibit as a "safety valve" on all inhibit protocols and decides during the session how strong he needs the inhibit to be based on the amount of excess high beta present.

After reducing the parietal high beta, he would move to the frontal lobes to start getting the executive function as well as inhibitory function working in the frontal lobes (inhibit 2-8 Hz and 20 30 Hz at FZ). Respondent 8 expected after this frontal training to see sleep improve, stability start, focus improve, and OCD symptoinology decrease. Moving next to CZ, he would expect more calming while continuing to improve the above symptomology in the frontal area. Next, he would move to F8 continuing to decrease excess high and low- activity, expecting more calming, improved impulse control, and decreased irritability. Training down this same activity at 02 would help with possible visual processing problem. If client is overaroused after the frontal training. Respondent 8 would use an SMR Protocol (2-7 HZ inhibit, 12-15 HZ reinforce, and 20-30 HZ inhibit) at P4 to help calm the individual. If client is fine, he would move on to reducing alpha.

To train down excess alpha. Respondent 8 would start at CZ hoping to continue calming and reducing attention/focus issues if present, or at least increasing clarity. Moving next to the posterior temporals, he targeted social integration issues such as limits and boundaries issues and poor social perceptions. Moving next to the Occipitals, the intent was to reduce the eyes open alpha with what may be a visual processing problem. Respondent 8 bases his protocols on the NREP results.

Respondent 9 (20 —years of experience) stated that his goal was to train Fz referenced to the linked ears, training 6 9 Hz suppression with eyes open, with reinforcement of SMR at Cz-linked ears used for stabilization. to counterbalance any overactivation due to the Fz suppression training. He also indicated the presence of a focal slowed spectral alpha peak at Fz in the 7-8 Hz range, separate from the "healthy" faster 10 plus Hz posterior alpha rhythm that attenuates with eye opening. "The symptoms suggest the anterior location due to the general complaint of 'depression and stress.' and more specifically they point to the locus of the anterior cingulate with 'motivational' and the 'perseveration' associated with chronic pain issues."

Respondent 9 stated that removal of the slowed alpha at Fz through the NF training may "overaetivale" the brain function, so the SMR training may be used in counterbalance with the Fz training as needed for stability.

The raw EEG provided all Respondent 9 needed, and he staled thai the data he worked ofT of are easily seen in either of the commercial quantitative software packages mentioned (NG and NREP).

Respondent 10 (5 10 years of experience) stated that he would recommend sessions of two or three times per week evenly spaced as much as possible. He also usually attempts to have the session last 30min. "If :he person fatigues after 25 minutes, I might push them to 27minutes and end.

Likewise if they are really in the 'zone' I might go until 40 or 45 minutes based on availability." He defined progress as client report of improved complaints *and* change in EEG. "Change in EEG may show learning but if the client doesn't feel better it is of no value. Change in complaints without EEG learning usually lasts no longer than a few sessions."

Respondent 10 always begins with an eyes open protocol to help the client identify and understand the process of neurofeedback. He starts with the first protocol mentioned (inhibit 6-9Hz and augment 12 18Hz at FZ referenced to linked ears) for several reasons. "It should be one of the easiest protocols for the client to learn, therefore, providing her with some initial success with training and also it is likely that she is able to feel some improvement." He based this protocol on the QEEG results; thinks the client will respond quickly to it; and correlated this protocol to the complaints of lack of motivation, pain, and sleep problems. "This protocol should be utilized at least 5 sessions and continued if the client reports progress. It should be discontinued when progress has plateaued or if there is no report of progress after 5 sessions."

Respondent 10 stated his second protocol (inhibit 1 7 Hz and augment 9-11 Hz and inhibit 15-32 Hz at 0Z referenced to linked ears) is more challenging because of the increased number of requirements. He added. "The eyes closed condition shows more aberration and stronger deviation than the eyes open condition." He thinks this protocol should address the complaints of pain, lack of motivation, sleep problems, and stress.

Respondent 10's third protocol (inhibit 1-7 Hz and augment 9-11 Hz and inhibit 15- 32 Hz at 0Z referenced to AFZ) is identical to the second with the exception of the reference. This protocol is designed to shift the anterior to posterior asymmetry and the potential elevated hypercoherence, "which appears mostly like a reference or noise problem." He stated this protocol should not be used more than three to five sessions without a new evaluation. He reasoned, "I think the findings of hypercoherence are reference contamination, but the asymmetry may need to be addressed."

He thinks his final protocol (inhibit 17 32 Hz at 0Z referenced to linked ears) is likely to be the most challenging to learn. "It tends to be difficult for the client to learn how to 'try not to try' and to actually reduce parietal and occipital beta." "This protocol would be aimed at complaints of stress, sleep and pain with possible implications in depression." Respondent 10 used both NREP and NG.

Comparison of Protocols/Rationales

The QEEG-based practitioners surveyed for this study closely agreed on certain aspects of their protocol recommendations and diverged significantly on other aspects. The following outcome information is summarized in Tables A1 to A5.

Site Commonalities and Differences

There was complete agreement among all respondents on treating the frontal lobe, though specific site recommendations varied, collectively including Fpl, Fp2. AF3 (between FP1 and F3), AF4 (between FP2 and F4). FZ. F3, F4. F7, and F8. Seven out of 10 respondents would also treat sites on the sensory motor strip, with sites named varying among CZ. CI, C2, C3, C4, and C6. Seven out of 10 respondents targeted the parietal lobe and would treat PZ. P3 and P4. Five out of 10 respondents would treat the temporal lobe and would treat T3, T4. T5, and T6. Only 4 of the 10 respondents recommended treating the occipital lobes: 2 would treat at 01 and 02, 1 would treat at 0Z and 02, and I would treat at OZ and POZ. Comparison of subgroups within this survey sample (those having 5-10 years of experience and those with 20 I years of experience: see Table A2) showed that the two subgroups did not differ significantly in their site recommendations. Respondent comparisons of site commonalities and differences can be found in Tables A3 and A4.

Bandwidth Commonalities and Differences

The majority of respondents were in consistent agreement as to which brain wave frequency band widths to train, though sites varied among the brain regions in question. There were also slight discrepancies as to whether to inhibit or reinforce the agreed- upon bandwidth activity. Respondent comparisons of bandwidth commonalities and differences can be found in Table A5.

Sequence Commonalities and Differences

Half of the 10 survey respondents would begin by treating the frontal lobe (one also included parietal), whereas 4 of 10 respondents would start with the sensory motor strip. Two respondents would start with the parietal lobe (one also included frontal), and 1 respondent would begin in the occipital region. So there was a preference among the majority of these neurofeedback providers to begin treatment in the frontal lobes and/'or sensory motor strip. The majority of the 20 i year subgroup (3 of 5) would begin treatment frontally. Two of the five 5- to 10-year experience subgroup would start on the sensory motor strip, whereas one of the five 20 —year subgroup started at this location. Other differences in sequence between these two subgroups were unremarkable (see Table A6).

Rationale Commonalities and Differences

There was almost total agreement (with one exception) that the elevated 1 Hz delta activity, seen in the QEEG should not be addressed in treatment because it (activity at 1 Hz that does not go beyond 1 Hz) is suspected by many to be an artifact.

Three of the respondents (Respondent 10) from the 20-f-year experience subgroup and 2 from the 5- to 10-year experience subgroup (Respondents 2 and 6) identified a reference- driven artifact. As Respondent 2 noted. "The eyes closed condition is tainted by a driven reference artifact that collapses the NEI frontally in theta and alpha and to some degree in beta. This artifact leads to hypercoherence in the alpha band and is throwing off other readings as well." Respondent comparisons of additional input in the QEEG record can be found in Table A7.

Training Commonalities and Differences

Four of the 10 respondents would do an "all inhibits" protocol with this case, whereas 5 of 10 respondents would use a mix of inhibits and reinforcers. Only one respondent would use all reinforces.

Several respondents shared unique input regarding their training methods. One respondent (Respondent 2) noted that he controls for artifact by suppressing 1-3 Hz. Another (Respondent 8) inhibits 20-30Hz as a "safety valve" for all inhibit protocols. In addition, some of the respondents specified the number of sessions they would complete at each site with this case. This information generated additional questions from the surveyors.

Each respondent was asked several brief follow-up questions: (a) How many minutes do your clients generally train? (b) In general. what is the average number of sessions you do per site clients? (c) What determi- nant/method(s) do you use to know when to move to the next site (i.e., number of sessions, percentage of amplitude change.

report of symptom change, etc.)? (d) On average, what is the total number of sessions per client? and (e) How many sessions will be done on an unresponsive site? Respondent comparisons of training commonalities and differences can be found in Tables A8 and A9. The following is a summary of the average ranges reported by the survey respondents.

The range for usual training time per session was 15 to 40min. with 20 to 30min appearing to be the average. Fifteen-min training was stipulated for new clients in the early stages of neurofeedback treatment, whereas a client showing motivation to continue a successful session might be encouraged to continue to up to 40min.

The range for the average number of sessions per site was as little as one session for respondents whose approach was either to move around the head or to use the Sweet Spot method (which also involves adjusting and moving frequencies "on the fly," and as high as 20 sessions for respondents who continue to see and hear reports of gains at a particular site).

Respondents were in relative agreement on three main factors used to determine when to move from one training site to the next. The determinants were (a) the client's learning curve and ability to demonstrate "EEG learning," (b) changes in the EEG (i.e., decrease in amplitudes and/or decreases in the variability of the waveform). and (c) symptom/behavior change or the lack thereof. Only two respondents replied to the question about how long to remain on an unresponsive site. Respondent 6 said 3 to 5 sessions, and Respondent I said 15 to 20 sessions. The average number of total treatment sessions per client ranged from 20 to 60, with considerations given for the client's learning curve as well as his level of complexity/severity of symptoms.

DISCUSSION AND CONCLUSIONS

The recommendations provided by this small sample of QEEG-based neurofeedback practitioners contained some areas of consensus but also considerable differences in how they would proceed with neurofeedback treatment, even though most provided clear theoretical or research rationales as bases for their recommendations. It was apparent that some respondents were clearly relying on clinical experience, published data, and theoretical conceptualizations in addition to the objective QEEG findings as they formulated treatment strategies, which may be speculated as reflecting common practice among QEEG-guided practitioners in the field. This study was not designed to determine the clinical validity of the various protocol approaches reported. Because it can be assumed that the practitioners responding to this survey have been doing neurofeedback with some success for 20 or more years using the QEEG-based methods they described in their responses, a tentative conclusion that could be derived from this study is that if appropriate treatment sites and frequency ranges are targeted, there is more than one way to do effective neurofeedback, even when using QEEG as a basis for protocol selection. These findings may provide impetus to the field for further research into the mechanisms that contribute to good clinical outcomes when varying neurofeedback approaches are used.

A limitation of this study is that it was administered to a relatively small, nonrandom sample of experienced neurofeedback providers known to use QEEG. No conclusions can be drawn about the actual effectiveness of any of the protocols described by respondents, as this was beyond the scope of the study and none of the protocols recommended was used in the survey participant's case.

A future study might seek to compare protocols used in very similar cases to evaluate the efficacy of different QEEG-based treatment approaches. In addition, a similar study might be administered to neurofeedback providers experienced in using symptom/neurophysiological function-based or other approaches that do not include QEEG in protocol selection decisions.

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APPENDIX

TABLE AI. Protocol sites and sequences.

Seq	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
1st	FZ . 6-9 Hz 1 20-30 Hz	F7&P5 (P3/T5) | 8-15 Hz i 18-24 Hz	C3& C4 SMR (12-15HZ)	C3 and/or C3-FZ seq I 15-18Hz C4 and/or C4-PZ seq T 12-15 Hz	Fp02 1 2-7 Hz r 15-18 Hz	C5-C6 & C1-C2 Experiment 12-7 I 2-13 I 20-30 i 14-30 T 8-11 Sweet Spot Ranges: 0- 3 or 15-18	01 & 02(2) i 5-15 Hz	PZ I 18-25 If Needed: Same at P3 & P4	FZ 1 6-9 Hz CZ SMR	FZ (EO) . 6-9 Hz T 12-18 Hz
2nd	PZ | 18-30 Hz	Re-map after 15-20	PZ 1 18-30 Hz 1 10-12HZ	F3-F4 seq and/or FZ T 1-7 Hz EC	F1 & F2 I 1 Hz	Sleep impr. - Contin- l C5-AF3	| Co Alpha @ LFT RPT	FZ i 2-8 i 20-30		OZ (EC) Ref-ears 11-7 | 9-11 | 15-32
3rd	P3 i 18-30 Hz		FZ] 6-11 Hz 1 14—18 Hz	C3/C4 and /or CZ T 1-7 Hz EC	F3& F4 I 1 Hz	C5-AF3 & C6-P4 use Sweet Spot Ranges	F3 & RPT I 17-21(2)	CZ \ 2-8 1 20-30		OZ (EC) Ref-AFZ 1 1-7 T 9-11 i 15-32
4th	T5 1 7-10 Hz i17-30 Hz		F3 [6-11 Hz R 14-18 Hz	Fp1-Fp2-s * 12-15 Hz F3-F4 seq 1 12-18 Hz	T3&T4 I 1 Hz	AF3-AF4 & CP5-CP4 Adj. to SSRanges	i Co Alpha @ RFT-LFT	F8 J 2-8 | 20-30		POZ (EO) [17-32 Ref-ears

TABLE A1 (continued)

Seq	R1	R2	R3	R4	R5	R6	R7	R8	R9
5th					C3& C4 J 1 Hz	C6-AF4 & C6-P4	F4& LPT(2) I 13-21	02 1 2-8 1 20-30	
6th					T5 & T6 I 1 Hz		1 Co Alpha @ F3-CZ/C4	If arousal: P4 12-7 Î12-15 i 20-30	
7th					01 & 02 i 1 Hz	I Co Alpha	T5-CZ/C4	CZ { 8-13 1 20-30	
8th					P3& P4 J 1 Hz			T5 1 8-13 I 20-30	
9th					PZ & P4 i 21-30 Hz Î 10Hz			T6 J 8-13 i 20-30	
10th					P3/02 I delta coherence			OZ i 8-13 1 20-30	

TABLE A2 (continued)

	5-10 Years' Experience					20 + Years' Experience				
Seq	R1	R4	R6	R8	R10	R2	R3	R5	R7	R9
5th			C6-AF4 & C6-P4	02 12-8 .20-30				C3 & C4 11 Hz	F4 & LPT{2) 113-21	
6th				If arousal: P4 12-7 712-15				T5&T6 11 Hz	ICO Alpha ©F3- CZ/C4	
7th				120-30 CZ 18-13				01 & 02 11 Hz	ICo Alpha @T5-	
8th				[20-30 T5				P3 & P4	CZ/C4	
9th				18-13 120-30 T6 ¿8-13				11 Hz 121-30 Hz | 10 Hz		
10th				120-30 OZ .8-13 1,12-30				PZ& P4 P3/02 I delta coherence		
4th	T5 17-10 Hz 117-30 Hz	Fp1-Fp2-s r12-15 Hz F3-F4 seq 112-18 Hz	AF3-AF4 & CP5-CP4 Adj. to SSRanges	F8 12-8 120-30	115-32 POZ (EO) 117-32 Refears		F3 16-11 Hz 114-18HZ	T3& T4]1 Hz	I Co ICo ©RFT-LFT	

TABLE A3. Respondent comparisons of site commonalities and differences.

Respondent	Frontal Lobe	Sensory Motor	Parietal Lobe	Temporal Lobe	Occipital Lobe
1	FZ		PZ P3	T5	
2	F7		P3	T5	
3	FZ F3	C3/C4	PZ		
4	F3-F4-s and/or FZ (EC) Fp1-Fp2-s F3-F4-s	C3 and/or C3/FZ C4 and/or C4/PZ C3/C4 and/or CZ (EC)	(PZ)		
5	Fp02 F1 & F2 F3& F4	C3 & C4	P3& P4 PZ& P4 P3 (& 02)	T3&T4 T5&T6	01 & 02
6	AF3-AF4 (& CP5-CP4)	C5-C6 & C1-C2 C5-AF3 (and C6-P4) C6-AF4 (and C6-P4)	P4		
7	F3 & RPT F4	(F3)-CZ/C4 (T5)-CZ/C4		T5	01 & 02
8	FZ. F8	CZ	PZ P3& P4	T5, T6	02, 0Z
9	FZ	CZ			
10	FZ				OZ, POZ
Level of agreement	10/10	7/10	7/10	5/10	4/10

TABLE A4. Subgroup comparisons of site commonalities and differences.

Respondent	Frontal Lobe	Sensory Motor	Parietal Lobe	Temporal Lobe	Occipital Lobe
1	FZ		PZ P3	T5	
4	F3-F4-s and/or FZ (EC) Fp1-Fp2-s F3-F4-s	C3 and/or C3/FZ C4 and/or C4/PZ C3/C4 and/or CZ (EC)	(PZ)		
6	AF3-AF4 (& CP5-CP4)	C5-C6 & C1-C2 C5-AF3 (and C6-P4) C6-AF4 (and C6-P4)	P4		
8	FZ. F8	CZ	PZ P3 & P4	T5, T6	02. 0Z
10	FZ				OZ. PZ
Subgroup (5-10 years exp.) level of agreement	5/5	3/5	4/5	2/5	2/5
2	F7		P3	T5	
3	FZ F3	C3/C4	PZ		
5	Fp02 F1 & F2 F3& F4	C3& C4	P3& P4 PZ&P4 P3 (& 02)	T3&T4 T5&T6	01 & 02
7	F3 & RPT F4	(F3)-CZ/C4 (T5)-CZ/C4		T5	01 & 02
g	FZ	CZ			
Subgroup (20+ years exp.) level of agreement	5/5	4/5	3/5	3/5	2/5
Combined level of agreement	10/10	7/10	7/10	5/10	4/10

TABLE A5. Bandwidth Agreement.

Respondent	Frontal	Central	Parietal	Temporal	Occipital
1	6-9|		PZ & P3 18-301	T5: 7-101 17-30|	
2	F7: 8-15| 18-24]		P5/P3: 8-151 18-241	T3: 8-15t 18-241	
3	6-11.| 14-18|	C3 C4-12-15	PZ: 18-301 10-121		
4	F3-F4 or FZ 1-7T	C3&C4 12-15 or 15-18			
5	F1 F2 F3 F4 11 Fp02: 2-71 15-181	C3 C4: 1]	P3 P4: 11 PZ P4: 21-301 ior	T3 T4 T5 T6: 11	01 02: 11 P3-02 Delta- coherence
6	n/a	n/a	n/a	n/a	n/a
7	F7 Fp1 F3 Alpha Co|	CZ/C4 Alpha Co i -F3& -T5	P4 (RPT) 17-211	T6 (RPT) 17-21]	01 02 5-151
8	2-6 i	2-8 i 8-131	18-25i	T5 T6 8-131	02: 2-81 0Z: 8-13.
9	6-91	SMR			
10	6-91 12-181				0Z: 1-7J EC 9-111 EC 15-321 EC 17-321 (EO)
Level of bandwidth agreement	7/9 Delta and theta Ranges	5/6 Alpha and Lo Beta Ranges	5/6 High Beta Range	3/4 Alpha range	3/4 Delta-theta range

TABLE A6. Respondent and subgroup comparisons of sequence commonalities and differences.

Respondent	Start w/Frontal Lobe	Start w/Sensory Motor	Start w/Parietal Lobe	Start w/Temporal Lobe	Start w/ Occipital Lobe
1	X				
2	X		X		
3		X			
4		X			
5	X				
6		X			
7					X
8			X		
9	X	X			
10	X				
Level of agreement	5/10	4/10	2/10	0/10	1/10
Subgroup					
1	X				
4		X			
6		X			
8			X		
10	X				
Subgroup (5-10 years exp.) level of agreement	2/5	2/5	1/5	0/5	0/5
2	X		X		
3		X			
5	X				
7					X
9	X				
Subgroup (20 years exp.) level of agreement	3/5	1/5	1/5	0/5	1/5
Combined level of agreement	5/10	3/10	2/10	0/10	1/10

TABLE A7. Respondent comparisons of additional input.

Respondent	Identified Elevated 1 Hz Activity as Artifact	Identified Driven Reference Artifact	Control for Artifact by Suppressing 1-3 Hz	Inhibit 20-20 Hz as a "Safety Valve" for all Inhibit Protocols	Up Train Slow Waves	1 Session Per Site to Move Around the Brain
1	X X	X	X			
2						
3	X					
4	X				X	
5						
6	X	X				
7	X					X
8	X			X		
9	X					
10	X	X				
Level of agreement	9/10	3/10	1/10	1/10	1/10	1/10

TABLE A8. Respondent comparisons of training practices.

Respondent	All Inhibits	All Enhances	Mixed
1	X		
2			X
3			X
4		X	
5			X
6			X
7	X		
8	X		
9	X		
10			X
Agreement	4/10	1/10	5/10

TABLE A9. Respondent comparisons of training practices.

Respondent	Training Time Per Session	Average Number of Sessions per Site	Determinant to Move to Next Site	Average No. of Total Sessions	Max No. of Sessions on Unresponsive Site
1	15-20 min Increase to 30-40	Coherence 3-7 Amplitude 10-30	Shift in activity or behavior they can maintain, or no change	Minimum of 30, up to 1004- for more severe. Average = 50-60	15-20
2 o	15-20 min	20	Follow-up evaluation including QEEG		
o 4	30 min (may start w/20)	10 as an estimate	EEG learning; Symptom improvement; EEG changes		
6 7	15-45 min	1-20	Behavioral goals EEG changes	20-25 = average person 4-60 (complexity)	3-5
i 8	30 min	Site 1: 12-15 Site 2: 6-8 Site 3: 4-6 Continue: 4-6	Site EEG changes (reduction of variability and decrease of amplitude. and symptom changes	40	
9	30-45 (1 per day) 3-4 per week; reduce to 1-2 per week; then fewer	Depends on client's learning curve	Depends on client's learning curve	15-20 = Clinical impact; 20-30 = stable results for attention deficit hyperactivity disorder	
10	30 min 25-40 (pending tired or alert)	5-15	Complaint reduction & EEG learning	Depends on Client	
Agreement range	15-40	1-20	Behavior change/not EEG change Learning curve	20-60	3-20

Note. QEEG quantitative electroencephalography.

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PROCEEDINGS OF THE 2008 ISNR CONFERENCE

Selected Abstracts of Conference Presentations at the 2008 International Society for Neurofeedback and Research (ISNR) 16th Annual Conference, San Antonio, Texas

The 16th annual conference of the International Society for Neurofeedback and Research (ISNR) was held in San Antonio, Texas, on Labor Day weekend 2008. More than 400 people attended this meeting, and Leslie Sherlin, PhD, Conference Committee Chair, was congratulated numerous times for organizing such a wide-ranging and successful venture. If you happened to miss the meeting, or missed a talk or two, what follows are presentation abstracts along with the e-mail addresses of the presenters whenever available.

David A. Kaiser. PhD
Editor

Pre- and Post-QEEG and Neuropsychological Effects of Left Frontal Magnetic Stimulation (rTMS) in Depression

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Background

rTMS treatment for depression has been under investigation in many controlled studies over the last 20 years. These studies have shown mixed results. Most studies used a single stimulation protocol to treat all patients in the same way. Furthermore, the population investigated consisted of treatment-resistant depressed patients. Little is known about interindividual differences, contraindications for treatment, and the neurobiological action of rTMS in patients. We therefore developed a personalized stimulation protocol based on the QEEG and neuropsychological data and investigated pre- and posttreatment effects on QEEG and neuropsychology.

Methods

rTMS treatment was applied in 8 participants for a maximum of 20 sessions to the Left Dorsolateral Prefrontal Cortex (Left DLPFC). Prior to treatment clients were assessed on a full QEEG and neuropsychological (IntegNeuro) evaluation. First, potential contraindications were investigated, for example, paroxysmal EEG activity and focal excessive beta spindles. Clients were stimulated over the left DLPFC with 10 Hz rTMS. Furthermore, rTMS treatment was complimented by cognitive behavior therapy.

Results

All participants showed full remission within 20 sessions and there was a 65% reduction in depressive symptomatology (BDI score) in 15 sessions. There was also a clear decrease in the Neuroticism scale of the NEO-FFI personality questionnaire. Pre- and post-QEEG, neuropsychological assessments, and FRP effects are currently under analysis and will be reported during this presentation.

Discussion

The results of this pilot study demonstrate that rTMS is an effective and sale treatment for patients with depression. Pre- and post- QEEG measurements, neuropsychological assessments, and event-related potentials will be presented during this presentation.

Optimizing Microsurgical Skills with EEC Neurofeedback

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Background

Neurofeedback has previously been found to improve cognitive performance as well as artistry by enabling individuals to self- regulate their brainwave activity. We assessed whether two distinct EEG neurofeedback protocols could enhance surgical skill, given the decisive role this skill plays in medicine.

Methods

NHS trainee ophthalmic microsurgeons ($N = 20$) were randomly assigned to either sensorimotor response (SMR) and Alpha-Theta (AT) protocols or a waitlist "no-treatment" control group (.V=8) subsequently randomized to the training protocols. Both groups received eight 30-min sessions of EEG training. Pre- and postassessment included a skills lab surgical procedure with objective timed measures and expert ratings from video recordings by consultant surgeons, together with state/trait anxiety self-reports.

Results

SMR training demonstrated advantages not present in the control group. There was improvement in surgical skill according to (a) the expert ratings: overall technique (/> < .038) and suture task ($p< .018$; judges* reliability. $r = .85$); (b) task speed (total task time, /x.021), whereas everyday anxiety (trait) decreased by circa 10% ($p<.017$), and of importance, the decrease in anxiety and surgical task time were both associated with EEG training change.

AT training produced marginal improvement. evinced by overall performance time reduction, which was accompanied by a large standard error indicative of uncontrolled individual differences. Notwithstanding, successful within session elevation of the theta-alpha ratio correlated positively with overall technique ($r - .64$, $p = .047$).

Interpretation

SMR neurofeedback training provided significant enhancements in surgical technique while considerably reducing time on task by approximately 25%. There is also evidence that AT training marginally reduced total surgery time, despite suboptimal training efficacies. All in all the data set provides encouraging relationships validating the optimizing of performance on a complex professional skill through neurofeedback training.

EEG Phenotypes Predict Treatment Outcomc to Stimulants in Children With ADHD

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This study shows that the EEG Phenotypes as described by Johnstone, Gunkelman, and Lunt are clearly identifiable
BEG patterns that can be classified with high reliability by two raters. Furthermore, it was also demonstrated that these EEG phenotypes occurred in both attention deficit hyperactivity disorder (ADHD) participants as well as healthy control participants. The Frontal Slow, the Slow Alpha Peak Frequency, and the Low Voltage EEG Phcnotype seemed to discriminate ADHD participants best from the control group, however, not significantly. The frontal slow group responded to a stimulant with a clinically relevant decreased number of total errors and false negative errors on the CPT. It also became very clear that the two most prevalent F.EG Phenotypes Frontal Slow- and Slowed Alpha Peak Frequency—have in previous research most likely shown up as the typically found frontal theta group, whereas these two EEG Phenotypes have very different etiologies as evidenced by the treatment response to stimulants and the autonomic interrelations.

This implicates that all future research employing EEG measures in ADHD should avoid using filtered data only, but first establish whether a frontal slow or a slowed alpha peak frequency is present. Furthermore, the severity of the phenolype divergence from normal is greater in the clinical group than in the controls. This demonstrates that not only the presence of a phenotype but also the magnitude of the deviation from normal is related to "normalcy." Investigating EEG Phenotypes seem to be a promising new way to approach EEG data, explaining much of the variance in EEGs and thereby leading to more specific prospective treatment outcomes. We have chosen not to do pre-post statistics on this small group but will perform the effort when we get a larger group where the statistical power actually makes some sense.

An Evolutionary Approach to Brain Rhythms and Its Clinical Implications for Brain Modulation

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Introduction- Evolutionary Approach to Functional Anatomy

We have a brain because we need one. Evolution has created the brain that fits the environment. Looking at the evolutionary stages, a phylogenetically old automatic autonomic archencephalic reflex can be modified by an evolutionary more recent paleencephalic brain structure, dimming or increasing the response. This modulated response can. at a later stage of evolution, become integrated into a neencephalic plan and ultimately result in a controlled execution of the planned response.

Motor/autonomic responses require some cost/benefit (C/B) instructions, deciding about the allocation of responses in relation to various reinforcers. The nucleus accumbens, being a C/B instructor might instruct the ventral and dorsal striatum to form conditioned responses (both Pavlovian and operant) to the stimulus that released a burst in the VTA with resultant dopamine boost in the nucleus accumbens and prefrontal cortex.

Evolutionary Approach to Brain Functioning (Extending the Polyvagal Theory)

Steven Porges has described the polyvagal theory, based on a phylogenetic approach. Based on dopamine lateralization in controllable and uncontrollable stress and based on the lateralization studies of the autonomic system performed by Oppenheimer the polyvagal system can be heuristically extended to a five-step mechanism. At rest the myelinated vagus, controlled by the left insula is predominantly active (rest and digest). When a stimulus arrives that needs to be responded to (controllable stressor) the right insula is coactivated adding some sympathetic drive to the parasympathetic activity. When stress becomes uncontrollable the left insula shuts down vagal nerve activity and only right insular sympathetic activity prevails, and when stressors become life-threatening the activity shifts back to the left insula activating the unmyelinated vagus resulting in extreme rest (death feigning).

Primitive species, requiring little information processing suffice with slow oscillations, whereas phylogenetically more recent species such as humans have enormous processing going on, demanding more of the fast oscillations. The frequency of paleencephalic emotional pathways in the brain might be theta band activity, whereas the phylogenetically more recent cognitive activity might be alpha based.

The frequency of the spontaneous oscillations in the EEG and the level of consciousness are correlated: the higher the frequency and the lower the amplitude of the EEG, the higher the level of consciousness. Data from multiple sensory systems suggest that gamma waves (30-80 Hz) are a prerequisite for conscious perception of a sensory stimulus. Thus sensory awareness is correlated to gamma band activity in the sensory thalamocortical system. Synchronization of separate gamma-band activities, present in different thalamocortical columns, is proposed to bind distributed neural gamma activity into one coherent sensory percept.

However, studies in the olfactory system suggest that gamma activity is nothing more than a carrier wave and that the information transmitted occurs via amplitude modulation of the gamma carrier wave. One way of retrieving the information content is to decompose the gamma band activity via independent component analysis. If the other frequency bands are also carrier waves one message can be processed simultaneously by separate circuits, for example, limbic at delta/beta and cognitive at theta/gamma.

Bringing Jt All Together: A Hypothetical Tinnitus Model

At rest the auditory cortex oscillates at alpha frequencies (8-12 Hz). When there is hearing loss, the deafferented cells will initially oscillate at lower frequencies (4-7 Hz) because there is less information to be processed. Because of a decrease in lateral inhibition, there will be an associated halo of gamma band activity (30 80 Hz). This is called thalamocortical dysrhythmia.

At rest the limbic system oscillates at theta frequencies (4 7 Hz). When there is a deafferentation of limbic input associated with a sensor>' deafferentation (via the nontopographic pathways) the deafferented limbic cells will initially oscillate at lower frequencies (I 31 Iz.) because there is less information to be processed. Because of a decrease in ateral inhibition, there will be an associated halo of beta band activity (13-30 IIz). This is what is noted in distressed tinnitus patients in a right-sided "distress network." consisting of the amygdala, anterior cingulate. anterior insula, and BA10 (prefrontal cortex). By analogy this could be called limbic dysrhythmia. Synchronization of the thalamocortical dysrhythmia and limbic dysrhythmia—by. for example, phase synchrony ^ould then result in tinnitus distress.

Predictions

Based on this evolutionary heuristic model the following suggestions/predictions can be made:

- NFB as a form of operant conditioning can be most powerfully performed using implanted electrodes in the VTA or nucleus accuinbcns.
- NFB might be strengthened by dopaminergic medication targeting DI receptors.
- NFB at different targets should focus on restoring normal FFT activity of the dysfunctional circuit involved, for example, alpha for tinnitus intensity, theta lor tinnitus distress.
- NFB should aim at treating spectrally filtered and subsequently TCA decomposed activity.
- NFB should consider lateralization for modulation of limbic/autonomic activity.

The SMR Story: Sleep, Motor Regulation, and Memory

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The discovery of an EEG rhythmic pattern in the sensorimotor area of cortex in alert but motionless cats, dubbed the sensorimotor rhythm (SMR), was of particular interest because of its similarity to the unique "spindle-burst" pattern seen in the EEG of cats and humans during quiet sleep (Sterman & Wyrwicka, 1967). Both were in the 12-15 Hz frequency range over this general region and both were associated with the absencc of spontaneous motor behavior. In addition, the SMR appeared when animals were trained to suppress a learned motor response. To test the possibility that the changes in motor regulation in both states were related, a study was carried out in which cats were trained to produce the SMR directly in an operant conditioning paradigm, and sleep F.FG and structure were measured before and after this training (Sterman. Howe, & Macdonald. 1970). When compared to an alternate EF.G training condition in a counterbalanced, crossover design, sleep spindle density was significantly increased and the duration of sleep periods prolonged only following the SMR training condition.

A follow-up study with random assignment and double-crossover design provided SMR and control EEG training conditions to human participants. Sleep studies obtained before and after these training periods revealed a significant and unique increase in sleep spindle density specifically following SMR training. Collectively, these finding suggested a functional link between the SMR and sleep-spindle EEG patterns that was subsequently investigated by others. Hauri (1981) found that SMR neurofeedback training significantly improved the sleep of so-called idiopathic insomniacs who were not suffering from stress or transient tension. More recently Verstraeten, in a blinded, randomized, placebo controlled study, found that SMR training sessions prior to sleep significantly improved sleep latency, sleep stability, and sleep efficiency in a group of healthy adults, whereas Hocdlmoscr and others (in press) obtained similar results in a randomized, controlled study of SMR training and sleep but also demonstrated a significant increase in sleep SMR frequency and spindle number. Further, they found significant improvements in memory performance in SMR-trained participants after sleep. The involvement of SMR training in motor regulation and learning potentiation appears to mediate these outcomes.

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A Proposal for Combining Measures of Electric, Magnetic, and Chemical Gradients to Optimize Brain Imaging of Large-Scale Activity

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The common factor that underlies several techniques for brain imaging is the electric current by which dendrites express the magnitudes of their responses to synaptic inputs, sum them, and transmit their sum to the trigger zones of axons for transmission without attenuation locally and to the far reaches of the central nervous system. The high current densities in parallel dendritic shafts support magnetic field gradients of sufficient intensity to be detectable several centimeters from the scalp in the MEG. The broad distributions of the loop currents outside the dendrites manifest electric field gradients observed in potential differences in the scalp EEG. The prodigious demands for the energy that is required to drive the dendritic currents are met by metabolic and hemodynamic responses (inclusively "chemical gradients") that are observed with PET, BOLD, fMRl, and related techniques.

For all three of these state variables the relationships between the intensities of neural electric current density and the electric, magnetic, and chemical gradients are complex and far from proportionate. The observable state variables are complementary because the information they convey comes from differing sources, so that efforts to cross-validate localization of neural activity relating to specified cognitive behaviors have been disappointing. A more appropriate use for the three methods in combination is proposed through the noninvasive study of large-scale, high-resolution spatial patterns of neural oscillatory activity in the beta and gamma ranges. This approach would use multivariate statistics to classify and evaluate nonlocal macroscopic brain activity patterns that simultaneously occupy both gyri and sulci in the cerebral hemispheres. To the extent that various sensors obtain samples over comparable time segments, ihis approach may support cross- validation of the techniques and provide for better modeling of the multifactorial nonlinear relations between each observable state variable and the underlying neural activity.

Whole-Brain Functional Training Lsing Multivariate Proportional Z Scores

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This talk will describe a new method and present clinical results with a new method of training EEG connectivity and differential brain activation. This approach uses a novel multivariate approach to using normative EEG statistics. The method is based on the creation of new feedback variables, which are derived from live Z scores, in combination with other training criteria. This method goes beyond conventional single-component training and employs multiple brain metrics including absolute and relative power, power ratios, coherence, phase, and asymmetry. Values may be used individually or in various combinations. In its fullest expression, the method creates a simple training variable that reflects a comprehensive set of brain states and trains the brain to seek them. This results in whole-brain training while avoiding some important limitations of single-component training. QEEG studies of pre- and post-assessments clearly show that this method is capable of resolving multiple EEG abnormalities and that the system successfully targets relevant abnormalities, without the need to design specific protocols.

Systems Theory of Neural Synergy: Neuroanatomies! Underpinnings of Effective Intervention Using Neurofeedback Plus Biofeedback

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Introduction

Clinical experience indicates that, for the most part, clients present with problems in live key areas. These are (a) attention deficit hyperactivity disorder (ADHD) symptoms of inattention and impulsivity; (b) anxiety, depression, and affect modulation; (c) empathy. affect interpretation, and expression and maintaining social interactions; (d) executive function difficulties including learning and memory; and (c) movement problems, including tics. A comprehensive understanding of the interplay of central nervous system (CNS) components that underlie these difficulties requires that the practitioner perceive the human nervous system as a dynamic network of interconnecting elements that is constantly working to maintain homeostasis and equilibrium. Input to any element within the nervous system will produce change in the other elements of the system. These elements are synergistic: they work together producing correlated action where the product is always greater than the simple sum of the parts primarily involved. This is ihe basis of our work with hundreds of clients and we have recently developed the Systems Theory of Neural Synergy (STNS) to explain why it works to combine neurofeedback, biofeedback (polyvagal theory), cognitive strategies (CS). and at limes music therapy. Each approach feeds back to and through the CNS and supports and facilitates the feedback through other modalities. The participants will be introduced to how lack of normal functioning in cortical, diencephalic, corpus striatum, midbrain, and brain stem regions can correspond to the clients' symptoms.

Method

Clinical assessment including 19 channel quantitative electroencephalography plus low-resolution electromagnetic tomography, indicates areas of dysfunction that correspond to a client's symptoms. As an example, in autistic spectrum disorders including Asperger's, these include (a) prefrontal cortex, (b) hippocampal gyrus, (c) amygdala with its connections to the orbital and medial frontal areas of the brain, (d) fusiform gyrus, (e) superior temporal gyrus containing the auditory cortex, (0 anterior insula and the anterior cingulate (both part of the limbic system, or emotional brain), and (g) frontal and parietal-temporal mirror neuron areas (on the right side underlie sensory and motor aprosodia). Stephen Porges's polyvagal theory demonstrates how many of the symptoms observed in ASDs also have brain stem components that can be constructively influenced by creating a "safe" environment with biofeedback and sound feedback. For the majority of clients. recovery from stress is an additional difficulty and this can be demonstrated using a psychophysiological stress assessment. Intervention encompasses appropriate feedback to normalize the EEG and increase heart rate variability while relaxing muscles and increasing skin temperature, and coupling these feedback approaches with appropriate cognitive strategies for the particular client. Operant and classical conditioning come into play.

Results

The authors have presented and/or published on the successful outcomes of this approach for more than 150 clients with ADHD and another group with ASDs (145 with Asperger's and 9 autistic). They have also published on methodology and successful outcome with anxiety /depression and stress and on movement disorder. The measurement of clinical success will be shown with data from ease series.

Conclusions

The STNS helps the practitioner to understand the CNS as a gestalt. This leads to a foundation that supports the combined use of NFB, BFB. and cognitive strategies to ameliorate the presenting problems of clients.

LORETA Neurofeedback in the Cognitive Division of the Anterior Cingulate Gyrus in Monozygotic Twins Concordant for Attention Deficit/Hyperactivity Disorder

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Introduction

This study examines the effects of LORETA Neurofeedback (LNFB) in the cognitive division of the anterior cingulate gyrus in monozygotic twins concordant for Attention Deficit/Hyperactivity Disorder (ADHD).

Methods

Two 24-year-old men concordant for ADHD (predominantly inattentive type) since childhood underwent LNFB sessions: Twin 1 (Tl) completed

30 sessions; Twin 2 (T2) completed 15 sessions. Each session consisted of pre- and post-3-min eyes-closed and eyes-opened baselines and four 5-min training rounds conducted three times per week. We trained the individuals to increase 14-18 H/ activity on the AC. Learning was assessed by electrophysiological measures.

Results

Frequency analysis indicates significant learning occurred in the AC over sessions for Tl and in regions shown to share functional connectivity with the AC. Although

T2 completed less sessions moderately significant learning is shown. Frequency specific learning curves arc shown in theta, alpha 2. and beta frequencies, with significant decrease in delta in frontal regions.

Discussion

Further region of interest analysis suggests the trained frequency influences regions different than the same LNFB training protocol in normal participants, namely. BA 9 and 10 in left medial anterior regions. BA 6 in right frontal regions and BA 19. 7 and 40 in occipital regions. Discernible differences in ROI patterns will be explored further and presented.

A Comprehensive Review of the Psychological F.ffects of Brainwave Entrapment

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Objective

Brainwave entrainment (BWE), which uses rhythmic stimuli to alter brainwave frequency and thus brain stales, has been investigated and used since the late 1800s. We discuss its potential by presenting a systematic review of the literature from peer-reviewed journals on the psychological effects of brainwave entrainment.

Data Sources

Terms used to describe BWE and psychological outcomes were used to search English language studies from OVID Medline (1950 2007), Psyclnfo (1806-2007). and Scopus.

Study Selection

More than 20 studies selected satisfied the following criteria: studies needed to use rhythmic stimuli with aims of affecting psychological outcomes. Peer-reviewed experimental and quasi-experimental studies were accepted. Case studies and review articles were excluded. Psychological outcomes were measured using standard assessment methods or deemed appropriate by peer review.

Data Extraction

Other clinical measurements, including EEG response, galvanic skin response, or neurotransmitter levels, were not included.

Data Synthesis

Psychological outcomes addressed cognition, stress and anxiety, pain relief, headaches or migraines, mood, behavior, and premenstrual syndrome (PMS). Protocols included the use of single, alternating, ascending or descending frequencies, or were determined by the subject, using auditory and/or photic stimulation. Studies examined single session effects and/or longer term multiple session effects.

Conclusions

Findings to date suggest that BWE is an effective therapeutic tool. Persons suffering with cognitive functioning deficits, stress, pain, headache/migraines, PMS, and behavior problems benefited from BWE. However. more controlled trials are needed to test additional protocols with outcomes.

Treating Veterans Who Suffer from Fibromyalgia

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Fibromyalgia syndrome (FMS) is a controversial diagnosis in the medical community. The American College of Rheumatology has defined FMS as the presence of widespread musculoskeletal pain with 11 out of 18 positive tender points.
Comorbid depression, anxiety and stress- related disorders, fatigue, muscle stiffness, sleep disturbance, and cognitive fogging are commonly reported. The etiology and pathophysiology remain unclear, although there is general agreement that FMS is a disorder of aberrant central pain processing. Although Pregabalin has recently been approved by the FDA for its treatment, there are no universally accepted treatment algorithms. There is some evidence that several nonpharmacological interventions alone, or in combination, may be efficacious and these include relaxation training using EMG biofeedback, meditation-based stress reduction, cognitive behavioral treatment, education, and physical therapy. More recently, research by Afton showed that heart rate variability (HRV)

biofeedback may be a useful treatment for FMS, perhaps mediated by autonomic changes.

The proposed presentation (a) provides a current review of the research on FM. (b) discusses the different theories and conceptual framework for understanding this disorder, (c) presents the intervention efficacy data published to date, and (d) describes the preliminary findings of outcome from our FM Program at the Houston VA Medical Center. In brief, this program combines weekly education and support groups with a nonpharmacological modality (HRV biofeedback. cranial electrotherapy stimulation, or audiovisual stimulation). Progress is monitored using HRV spectral analysis and a packet of psychometric instruments. Preliminary outcome data, based on 6 participants. indícate that although the SDNN (a standard measure of HRV) did not show a statistically significant increase because of the very small sample size of 3 (the others did not have their post-HRV measures completed at the time of this write-up), the effect size was large (0.85). Similarly, the effect sizes for several major symptoms of FM did show substantial improvement (sleep, as measured by the Pittsburg, was large: 0.70; depression, as measured by the Center for Epidemiologic Studies Short Depression Scale, was moderate: 0.45; overall mood states, as measured by the Profile of Mood States, was also moderate: 0.51; decrease in fatigue was statistically significant with a moderate effect size of 0.59; decrease in tension/anxiety was statistically highly significant with a large effect size of 0.85).

In addition to symptom reduction, participants also showed increased use of adaptive and more positive beliefs and coping strategies. For instance, the effect sizes for adapting constructive beliefs and attitudes toward pain range from a small effect of 0.23 to a large effect of 0.81. Finally, the use of cata- strophizing, as measured by the Sullivan scale, showed a near significant reduction (with a moderate effect size of 0.52) and an increase in the use of time contingent versus pain contingent coping (effect size of 0.37). The presentation concludes with a discussion of the limitations and implications of the preliminary results.

Paradigms Lost: Intellectual Survival After Expulsion from the Operant Garden with LENS

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What is the relationship between the observed EEG signal and our observable effect on that signal using brain wave biofeedback? In standard EEG neurofeedback we influence the EEG signal by contingent reinforcement of EEG variables, but such changes in the EEG signal tend to be transient, whereas systemic changes in behavior (and presumably in the brain) are longstanding. The operant conditioning model is insufficient to explain efficacy and efficiency of EEG neurofeedback.

This presentation reviews other models which make it clear that new paradigms will emerge to account for our clinical success with neurofeedback. Othmer's regulatory challenge/exercise model is one. Pribram's holonomic digital signal processing model is another. Ochs's LENS demands an entirely different set of paradigms to draw upon if we are to find a model that satisfies us. Cranial nerve stimulation may be one example. Also FA Popp's biophotonic model appears to underpin an entirely new paradigm of intercellular communication allowing us lo glimpse a possible integration of the biophotonic model and the holonomic digital signal processing models. Conceptually. applications of field dynamics from biophysics represent an emerging paradigm shift, but the scientifically contaminated term "energy medicine" may obscure our vision for a while.

At the heart of all neurofeedback paradigmatic explanations are the "smart cookie" and "vanity" models. Beyond the various psycho biological mechanisms that allow the creature within to operate, we are dealing with an imagined higher order entity that we call the brain, which is intelligently trainable because it is drawn to look at itself.

Successful LENS Treatment of Obsessive-Compulsive Disorder

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The only two previous publications on the use of neurofeedback with obsessive- compulsive disorder (OCD) found that approximately 60 neurofeedback sessions were required for a successful outcome. This paper presents details of the treatment of an OCD patient using the Low Energy Neurofeedback System (LENS). An objective and the most thorough measure of OCD, the Yale-Brown Obsessive Compulsive Scale, was administered pre- and post treatment. In addition, subjective ratings of symptoms were obtained weekly, and external verification of changes obtained through two relatives. After only 30 sessions, the patient was symptom free and had withdrawn from two medications. Five further reinforcement sessions were conducted and follow-ups obtained with both the patient and a relative. The outcome of two more recent OCD cases treated with LENS and using the same outcome measures are also briefly reported.

It must be emphasized that this is an initial report of a case series utilizing LENS treatment for OCD. Titus, although still considered experimental, these encouraging results are supportive of published articles that have found LENS treatment effective with other conditions and suggest that LENS treatment might also produce results more rapidly than traditional neurofeedback.

Autobiographical Memory: Neural Correlates of Experience and Self-in-Experienee

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Introduction

This study examines correlations between scores obtained on a recently developed self-perception and experiential schemata assessment and neurophysiological activation patterns according to life area, childhood, adolescence and adulthood utilizing standardized low-résolut ion electromagnetic tomography (sLORETA).

Methods

This study was accomplished with 27 non-clinical undergraduate students. The participants in this study completed the Self Perception and Experiential Schemata Assessment while undergoing EEG recording. Responses were marked within the EEG record, extrapolated, and compared to baseline for significance. The responses for each subsection were entered into correlation analysis with the sLORETA activation maps.

Results

The data reveal correlations for the obtained scores in each life area show significantly different activity patterns for each life area in each frequency domain.

Discussion

Evaluation of childhood, adolescence, and adulthood correlate with regions shown active during episodic and self-referential autobiographic memory. Each domain of experience appears to be functionally related to different neuronal circuitry. It is possible that dendritic sources of more remote memories are pruned away over time except in cases of extreme emotional content or reconstructed memory. We discuss implications for both memory' trace theory and the standard consolidation model (SCM); moreover, the data appear to favor the SCM, as the hippocampus does not show positive associations with any of the experiential domains; however, there are numerous tasks involved in this study which upon further investigation may oiler insight into functional specificity.

Quantitative Electroencephalograph Effects as a Result of Single Session Respiratory Sinus Arrhythmia Feedback in an Anxiety Population

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Objective

Previous investigations of electroencephalographs (EEGs) during relaxation has identified increases in slow wave (theta and alpha) band power, correlations between increased levels of alpha activity with lower levels of anxiety, and autonomic changes characterized by decreased sympathetic activity. This study was carried out to determine the impact of a respiratory sinus arrhythmia (RSA) biofeedback device on quantitative EEG (QEEG).

Methods

Participants were 43 individuals reporting stress levels at least 1 standard deviation above the mean on the Perceived Stress Inventory who were randomly assigned into either a control

(concentration device) or experimental group (RSA biofeedback:
StressEraser). Participants in both groups were novices given a 15-min training on how to use the devices. The study recorded 19-channel EEG under baseline, stressor task, intervention, postbasclinc, and repeated stressor conditions. For each group QEEG analyses were computed.

Results

Ratios of alpha/bet a and to a lesser degree theta/beta increased to a significant level in sites 01 and 02 following RSA feedback. QEEG features of power and relative power exhibited trends worthy of future investigation in a larger sample. There were no significant differences in the concentration only control device group.

Conclusions

These findings suggest that RSA feedback may decrease arousal in areas critical to the experience of stress and anxiety and provides physiological evidence of changes produced by RSA feedback.

Progress of Neurofeedback: From Scientific Research to Clinical Application

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There is a significant gap between scientific research and clinical applications of neurofeedback. This gap must be reduced to contribute to the progress of empirically supported treatments and gain credibility from medical and institutional instances in Mexico and worldwide. To understand and face this challenge, we review the methodological difficulties related to scientific research in the field and the importance of overcoming these obstacles.

Not only does the clinical application of neurofeedback require an individual psychophysiological assessment to support protocol decisión making, its success relies on many important variables such as the patient's confidence and bond with the therapist.
However, reliable research to prove both neurofeedback's efficacy and specificity involves an empirical control of these variables. Finally, it would l>e interesting to make the most of a clinical setting planning multicenter research protocols, establishing common goals and methodology, to enlarge evidence-based applications of neurofeedback.

Executive Functions: A New Approach

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Although there is growing evidence for the efficacy of neurofeedback training, there is still some skepticism because of the methodological issues in studies published so far and the doubt of how this method might operate changes in EEG and clinical symptomatology. This lecture examines the executive functions (EF) and correlates the neuroanatomy of the prefrontal region, to these abilities. This knowledge will help us to develop better models to treat conditions where the EF are affected. An open discussion for surface targets and or methods for neurofeedback training is expected by the speaker.

How Modulating Hemispheric Specialization and Lnterhemispheric Interaction Enable Skilled behavior

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Hemispheric specialization for higher cognitive function in the human brain permits the acquisition and maintenance of highly skilled performance. There is a special role for the right hemisphere in the initial stages of skill acquisition, where conceptual labels are missing or tentative. As the conceptual structure of the domain becomes more elaborate, the analytic role of the left hemisphere becomes more dominant. Further, skilled behavior is made possible by different modes of hemispheric interaction. One mode is the specialization by one hemisphere for efficient processing in a particular cognitive domain. For example, the left hemisphere is specialized for phonetic perception and the right hemisphere is specialized for emotional prosody during auditory language comprehension. A second mode is parallel processing in the two hemispheres when the task is complex and the cognitive domain is within the repertoire of both sides, in that case, shielding the hemispheres from each other is beneficial. A third mode is error monitoring by one side of performance in the other. An example is left hemisphere specialization for visual word recognition (reading) but right hemisphere specialization for delecting errors in reading. These modes are made possible by selective activation and deactivation of one hemisphere or of different channels of the corpus callosum. Those channels therefore provide a target for EEG biofeedback as a means of achieving skilled behavior.

Effect of Psychoneurotherapy Upon Brain Electromagnetic Tomography in Individuals with Major Depressive Disorder

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Context

Recent advances in quantitative electroencephalography (QEEG) and brain computer interface (BO) technology provide unique and powerful tools that may significantly contribute to the development of psychoneurotherapies.

Objective

The main goal of this study was to test the effect of a QEEG-guided psychoneurotherapy (PNT) upon brain electromagnetic tomography in individuals with major depressive disorder (MDD). The central objective of this treatment was to teach depressed patients to change their negative thoughts and emotions while learning to modify the underlying brain activity through a BCT. We predicted that the treatment would significantly reduce depressive symptoms and QEEG abnormalities.

Methods

Twenty-seven participants (22 female and 5 male; age range = 27 58) participated in this study. The severity of depressive symptoms was assessed by the Beck Depression Inventory Second Edition (BDI II). EEG was recorded (Deymed Diagnostic, TruScan 32) before and approximately 1 month after the PNT from 19 scalp locations. Based on the results of spectral analyses, participants were taught during the PNT to modify their negative thoughts and emotional states while learning to reduce high-beta (18-30 Hz) activity in right fronlo-temporal/paralimbic regions. Participants met the therapist two times per week for twenty 1-hr sessions. Brain changes were measured through standardized low resolution brain electromagnetic tomography (sLOR ETA).

Results

Following treatment, there was a significant reduction of BD1-1I scores (/?<.(X)1), and 20 out of 27 (74%) participants did not meet the *DSM-IV*criteria for MOD. In addition. absolute power of high-beta (18-30 Hz) activity showed a significant reduction in the right lateral prefrontal cortex, right orbito- lrontal cortex, right insula, right subgenual cingulate cortex, and right anterior temporal pole. It is noteworthy that these brain regions play a key role in executive functions, emotion. or emotional self-regulation.

Conclusions

These findings suggest that the proposed PNT used in this study can significantly improve brain activity and reduce depressive symptoms in individuals with MDD.

Efficacy of Neurofeedback for Executive and Memory Function in Dementia: Preliminary Findings

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Introduction

Previous studies have shown that dementia is associated with reduced cerebral blood flow (CBF) and various quantitative EEG (QEEG) abnormalities including a reduction in the dominant alpha frequency. The purpose of this study is to test whether neurofeedback training to normalize abnormal EEG rhythms and increase CBF can improve measures of memory and executive function.

Methods

Twelve participants are currently enrolled, where half are randomly assigned to a waiting list control condition. All participants rcceive a comprehensive assessment of memory and executive function, and a QEEG assessment. Thirty sessions of QEEG-guided neurofeedback are administered, where a random half of participants also receive frontal CBF biofeedback during their sessions.

Results

Two treatment group participants and one control have presently completed the study. Compared to the control case, the treated cases showed improvements, ranging from modest to dramatic, in the Integrated Visual and Auditory Continuous Performance Test (attention and response control), the Rev Complex Figure (nonverbal rccall), Memory Assessment System List Acquisition (verbal working memory), the Behavior Rating Inventory of Executive Function-Adult Version (executive symptom self-report), and the Delis-Kaplan Executive Function System (DKF.FS) Verbal and Design Fluency, and Letter-Number Sequencing.

Discussion

These results should be interpreted cautiously because of low participant number. For example, neurofeedback appeared to worsen performance on the Wisconsin Card Sort and DKEFS Word Context tests. Six

additional participants are expected to complete posttesting in time for this presentation.

Personalized Pharmaco-EEG: Predicting Medication Responses

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This presentation reviews recent research in quantitative EEG and how it is predicting psychotropic medication responses. The results of the BR1TE study by Aspect Medical are reviewed along with the research on Referenced-EEG by central nervous system response. Clinical examples of how it is used, particularly in treatment resistant patients, are presented.

Hypermobility Syndrome—An Ideal Candidate for Neurofeedback

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Introduction

Hypermobility Syndromes arc genetic disorders where connective tissue abnormalities cause flexible joints which lead to injury and pain. Autonomic Nervous System dysfunction is a frequent comorbidity. Children with this disorder tend to also experience dyslexia, dyscalculia, and dyspraxia.

Methods and Results

Quantitative EEG findings on children with Hypermobility Syndrome aTe presented. A detailed single case study is outlined. The approaches used involved both neurofeedback and HRV biofeedback.

Conclusions

It was found that neurofeedback and HRV biofeedback were effective in reducing levels of pain and led to improved concentration and academic performance.

The Effect of the Low Energy Neurofeedback System on Children with ADHD

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The purpose of this study was to examine the effect of the Low Energy Neurofeedback System (LENS) on children who have been diagnosed with Attention Deficit Hyperacti- vity/Impulsivity Disorder (ADHD). In this study 10 children who had been diagnosed w ith ADHD were given 15 sessions of LENS treatment. The J&J C2 Plus 12 was utilized as the EEG Neurofeedback device giving LENS stimulations.

The study began with all the children receiving a LENS map as a pretest baseline. After baseline data were collected, the children were given one session per week for 15 weeks. All the children were given the same LENS protocols so that the amount of LENS stimulation given was the same for all research participants. After the 15-week treatment period was complete the children were given another LENS Map posttest. All participants were tested pre- and posttest with the Integrated Visual Auditory Continuous Performance Task (TVA-CPT) on the same days in which they received pre and post LENS Maps. The parents of each child were asked to complete the Conners' Parent Rating Scale short form. Pre- and post-CRS S where given to parents prior to and following all LENS Maps. Several one way analyses of variance were run on the data using SPSS for Windows. The data show significant differences between pre- and posttest EEG LENS Maps, IVA- CPT scores and CRS-S ratings. The data suggest that the LENS is an effective treatment for children who have been diagnosed with ADHD.

Reading Difference Topography as an Aid to Neurofeedback Remediation of Reading Difficulty

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Reading difference topography is a quantitative EEG (QEEG) technique that we have used in more than 150 participants as an aid to understanding the disturbed cortical physiology underlying reading difficulty. Typically there are increases in focal slowing over critical reading areas when the person reads. There are often decreases in coherence (connectivity) between those areas and other critical reading areas. When these abnormalities are normalized with neurofeedback done while the patient reads, their reading ability usually improves. There may be abnormalities in the eyes-open condition (not reading) that need to be normalized. Case histories are presented illustrating the types of abnormalities found.

Efficacy of Connectivity Guided Neurofeedback for Autistic Spectrum Disorder: Controlled Analysis of 75 Cases with a 1- to 2-Year Follow-Lp

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Introduction

Autistic disorders have multisystem impact with significant adverse effects on the development of the central nervous system. The ncurobiological study of autistic disorders has shown problems related to neural connectivity. This has been demonstrated at multiple levels of analyses including neuropathological, f\lRI, MR1-DTI, and EEG studies. As such, therapeutic interventions of significance should lead to improvements in neural connectivity. We have shown that specific connectivity guided EEG training approaches (a) are effective in reducing autistic symptoms, (b) lead to therapeutic changes on measures of EEG connectivity and power, and (c) ihese changes are localizable and predictable. However, studies have had relatively small sample sizes, we examined the effects of segments of treatment only, and there has never been a follow-up period without treatment to measure the persistence of these effects.

Method

One hundred children with a diagnosis of Autistic Spectrum Disorder were included, 75 in the experimental group and 25 composed a wait list control group. The experimental group received quantitative EEG (QEEG) connectivity guided neurofeedback for at least 35 sessions. Pre- and post-QEEG. neuropsychological, educational, and parent rating scale measures were used to measure outcome. In addition, 20 patients from the experimental group were reassessed I to 2 years following the completion of their treatment with the same measures to assess the persistence of the effects of treatment.

Results

Findings show significant reduction in autistic symptoms, improvement on neuropsychological and educational measures, and reduction in QEEG abnormalities, all at /X.01, when compared to the waitlist control group. Analysis of the follow-up sample showed no regression as compared to when they completed their treatment.

Conclusions

In the largest controlled study of neurofeedback for autistic spectrum disorder, the data suggest significant improvements and persistence of these effects even after treatment haj> stopped. The implications of these findings arc discusscd.

Noninvasive Brain Stimulation as a Neuromodulator)' Approach: Review on the Clinical and Neurophysiological Effects

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In neurology and psychiatry, like in all of medicine, symptoms of disease and the resulting burden of illness and disability' are not simply the consequence of the injury, inflammation, or dysfunction of a given organ. Instead they are ultimately the consequences of the nervous system's attempt to adapt to the insult. This plastic response includes compensatory changes that prove adaptive for the individual, as well as changes that contribute to functional disability and are thus maladaptive. In this context brain stimulation techniques tailored to guide individual plastic changes associated with neurological and psychiatric diseases might enhance clinical benefits and minimize adverse effects. For this lecture, T discuss the application of two noninvasive brain stimulation techniques—repetitive transcranial magnetic stimulation and transcranial direct current stimulation—to modulate activity in the targeted cortex or in a dysfunctional network, restore an adaptive equilibrium in a disrupted network for best behavioral outcome, and suppress plastic changes for functional advantage. I therefore review the mechanisms of these two techniques of noninvasive brain stimulation and their potential clinical utility in psychiatry and neurology.

Time-Frequency Components of Brain Connectivity: Methods and Examples

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Measures of linear dependence (coherence) and nonlinear dependence (phase synchronization) between any number of multivariate time series arc defined. The measures are expressed as the sum of lagged dependence and instantaneous dependence. The measures arc nonnegative and take the value zero only when there is independence of the pertinent type. These measures are defined in the frequency domain and are applicable to stationary and nonstationary time series. One important field of application is neurophysiology, where the time series consist of electric neuronal activity at several brain locations. Coherence and phase synchronization are interpreted as "connectivity" between locations. However, any measure of dependence is highly contaminated with an instantaneous, nonphysiological contribution because of volume conduction and low spatial resolution. The new techniques remove this confounding factor considerably. Moreover, the measures or dependence can be applied to any number of brain areas jointly, that is, distributed cortical networks, whose activity can be estimated with eLORETA (exact low resolution brain electromagnetic tomography). A time- frequency analysis of single-trial ERP data during word processing is presented.

Expanded Study and 1 Year Follow-Up of Treating Early Dementia with Low Energy Neurofeedback System

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Background

Examining cases of dementia of the Alzheimer's type, a pilot study was undertaken that revealed extensive posterior slowing (delta and theta) that progresses around the left temporal area. In addition, there were a significant number of amplitude asymmetries and significant coherence abnormalities found. 1'he Low Energy Neurofeedback System (LENS) specifically attempts to lower high-amplitude low frequencies. Therefore, the LENS system was applied to patients who had the characteristic posterior high amplitude lower frequencies with corresponding amplitude asymmetries and coherence abnormalities to examine what effcct the treatment method would have on deteriorating memory-.

Method

Quantitative EEGs (QEEGs) were done before and after LENS treatment in patients who presented with deteriorating memory and posterior slowing with amplitude asymmetries and coherence abnormalities. LENS treatments were administered with periodic LENS maps. After the LENS treatments were completed, a post-QEEG was done to determine the effects the LENS treatment may have had on the characteristic slowing and abnormalities originally presented in the patient.

Results

Patients reported improvements in their memories as subjectively determined by job performance and as reported by the patients' family members for cases that had early signs of the characteristic slowing and abnormalities. More advance cases did not respond with memory improvements but some cognitive improvements were noted.

Discussion and Conclusion

There seems to be a limit as to when the LENS system can be applied successfully to reduce the deterioration of memory. Further investigation of successful LENS treatment for memory decline was done 15 months after the LENS treatment was completed. Memory functioning seems to remain strong, and the follow-up QEEG is presented.

Intelligence and EEC Phase Reset: A Two-Compartmental Model of Phase Shift and Lock

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Objectives

EECJ phase reset involves a brief phase shift followed by phase synchrony and is the foundation of coherence and coupling between brain regions. The purpose of this study was to explore the relationship between EEG phase reset and Intelligence.

Methods

The EEG was recorded from 19 scalp locations from 378 participants ranging in age from 5 years to 17.6 years. The Wechsler Intelligence Test was administered to the same participants on the same day but not while the EEG was recorded. Complex demodulation was used to compute instantaneous EEG phase reset and phase shift duration and phase lock duration.

Results

Phase shift duration (40-90 ms) was positively related to intelligence (pC.OOOOl) and the phase lock duration (100-800 ms) was negatively related to intelligence ($p < .00001$) Phase reset in short interelectrode distances (6 cm) was more highly correlated to IQ ($p < .0001$) than in long distances (>12 cm).

Conclusions

Information processing occurs primarily in local regions of the brain and less in the long distant systems. EEG phase reset reflects neural resource identification and allocation. A two compartmental model of local field coupling and neuron synchrony to a preferred phase of local field potentials was developed to explain the findings. It is hypothesized that inhibitory neurons rapidly shift frequency and that iteration in excitatory loops determines phase lock duration, which is directly related to the magnitude of EEG coherence. The larger the number of neurons synchronized at each moment of time then the higher is performance on an IQ test. The duration of unstable phase dynamics and stable phase locking represent a bounded optimization process, for example, a too long duration of phase locking then less flexibility and a too-short phase shift then reduced neural resources.

Conioduhition and Coherence: Models of Magnitude and Phase Synchrony

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Introduction

Confusion about the concepts of coherence and comodulation has hindered their simultaneous use in assessing EEG synchrony. Coherence and comodulation arc models of phase synchrony and magnitude synchrony, respectively, spectral network properties that occupy distinct but adjacent cells on a proposed periodicity table. Child and adult EEG data were analyzed for coherence and comodulation in order to differentiate these properties empirically.

Method

Eyes-closed resting EEG was acquired and spectrally analyzed for 101 children and adults between ages of 5 and 35 years (34 female, 67 male; *M* age =17.5 years). Analysis focused on site connectivity of 10 frequency bands. Site connectivity refers to total coherence or comodulation associated with a site divided by number of contributing site-pairs.

Results

Posterior site coherence and comodulation both increased with age for frequencies below 30 Hz *(p* < .0001). Anterior site comodulation also increased with age (p< .0001). Maximum site coherence progressed anteriorly with age for alpha and sensorimotor response bands (/><.001), but no similar topographic pattern was found for site comodulation. Alpha comodulation at electrode site T5 exhibited the strongest age function (r = .75, *p* < .0001).

Discussion

Functional connectivity is a central principle of brain maturation. Site coherence and comodulation of low and moderate frequencies were found to increase with age at most sites and may be useful in evaluating regional differences in brain maturity. A model that associates coherence with feedforward activity and comodulation with feedback activity of the brain is proposed.

The Basic Application of Pharmaco-EEG in a Clinical Setting

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Pharmaco-EEG is a noninvasive method to help guide the choice of psychotropic drug treatment. Although Pharmaco-EEG was started in the 1960s, its application in psychiatry has, for the most part, been limited to research and has never made it into clinical practice. However, we have found that every quantitative EEG (qEEG) provides valuable information that a psychiatrist should be made aware. This presentation provides basic examples of the challenges and rewards of using qEEG data to help guide psychotropic drug treatment.

Neurofeedback and Motivational Interviewing Based Bio-Behavioral Treatment in Cocaine Addiction

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Introduction

Cocaine dependence is one of the most severe addictions associated with significant morbidity and mortality. Cocaine addicts are very difficult-to-treat population being featured by a low motivation to change their drug habit and are reluctant to enter inpatient treatment (Crits-Christoph et al., 1997). Motivational interviewing (Ml) is a brief psychotherapeutic intervention for behavioral change aimed to bring about rapid commitment to change addictive behaviors. Because of its brevity. Ml is best suited to enhance compliance and facilitate treatment engagement (Stotts et al., 2006). Neurofeedback training-based neurotherapy is one of the potentially efficacious nonpharmacologi- cal treatment options for cocaine addiction (Sokhadze et al., 2008). EEG changes in beta and theta power are typical for withdrawal from cocaine. Cocaine abusers who arc still taking drug often present excess amount of both low- and high-frequency EEG activity (Prichcp et al.. 2002). Thus cocaine users may benefit from EEG biofeedback protocol aimed on increasing sensorimotor response (SMR) (12-15 Hz) and decreasing theta (4 8 Hz) activity at the vertex that is commonly used in the treatment of attention deficit hyperactivity disorder (Monastra et al., 2005). We proposed that a combined application of neurofeedback and motivational interviewing techniques will result in an effective biobehavioral intervention for cocaine addiction.

Method

Cognitive, behavioral, and emotional deficits and level of their persistence in cocaine users undergoing behavioral treatment based on neurofeedback and motivational interviewing (MI) were explored in this study on 14 cocaine-dependent outpatient participants. Dense-array event-related potential (FRP) were assessed prior and following bio-behavioral intervention using cognitive tasks containing drug-related and generally affective cues, and during cognitive tasks aimed to test cortical inhibitory capacity, selective attention, and cortical functional connectivity. The study examined cue reactivity to drug-related stimuli (three-stimuli oddball task with pictorial and verbal stimuli) and executive functions (e.g.. cortical inhibition in Go-NoGo task, error monitoring in Eriksen flanker task, etc.) assessed during behavioral tests with ERP recording before and after 4-week long behavioral treatments. Along with behavioral and ERP measures during tests and IVA+ Plus test results, the treatment outcomes included cocaine use rate (urine and saliva screens), maintaining treatment retention, intent-to- treat, and psychiatric status (posttraumatic stress disorder, depression symptoms). Most participants tested positive both on cocaine and marijuana use on the intake stage. Each participant took part in 12 sessions of SMR up/Theta down training (30 min. twice a week) and up to 3 sessions of Ml. The neurofeedback session included blocks with "SMR increase," "SMR increase and Theta decrease," and "SMR/Theta" ratio increase.

Results

Most of the participants successfully learned to increase SMR rhythm but were less successful in simultaneous SMR increase and Theta decrease blocks. Increase of the SMR during successful neurofeedback sessions was accompanied by a general arousal increase as indexed by the parallel increase of low and high beta band power as well as a significant increase of the skin conductancc level and the number of non-specific skin conductance response frequency and skin temperature decrease. Participants who completed whole course of combined neurofeedback and MI intervention showed improvement on behavioral and ERP measures of selective attention and other executive functions and showed decreased reactivity to drug-related cues. Among the clinical outcome measures the most significant was decrease of depression scores (Beck Depression Inventory). The drug screens did not show decrease in cocaine use, however, the number of positive tests for marijuana use decreased significantly.

Conclusion

Ml happened to be a very useful in maintaining high level of the intent-to-treat and retention in this study. The results of this pilot study support the suggestion that a combination of MI with neurofeedback might be a promising approach to biobehavioral intervention for addictive disorders, and specifically for treatment of cocaine addiction in outpatient population.

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EEG Bispcctral Analysis: Applications in Monitoring Conscious Awareness, Medication Management, and Tracking Effectiveness of Treatment in Dementia

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EEG bispectral analysis is an advanced signal processing technique that can be used to assess coherence among different EEG frequencies. This method has been developed into an index of depth of anesthesia (BIS) and is widely used to monitor for conscious awareness during surgery. Research recently published in the *New England Journal of Medicine* comparing BIS to analysis of exhaled anesthetic is reviewed and critiqued. New results from a multicenter clinical research trial using EEG monitoring to manage administration of antidepressant medication are presented, and new data on using a new derivation of BIS, termed BIS-D, used to detect and monitor dementing illness are reviewed.

Clinical Outcomes in Addiction: A Large Neurofeedback Case Series

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Introduction

Addiction is a serious public health problem that has historically had low levels of success, though anecdotal reports of improvements following NT treatments are reported. The initial characterization of the EJEG/qEEG baseline phenotypes in addiction characterizes the underlying phytopathology in addiction, with phenotypes indicating both ovcrarousal and cingulated disturbance loading very strongly into this clinical group. The results of NF treatments guided by the qEEG phenotypes will be evaluated with pre-post neuropsychiatrie measures.

Method

The first 30 clients to complete the program were analyzed. Pre-posl quantitative EEGs. as well as testing for IQ. thinking ability, cognitive efficiency, audio-visual learning ability, delayed recall, working memory, and sobriet} abstinence were collected and analyzed to evaluate the impact of NF and treatments on the clients performance on the various testing.

Results

The pre post outcomes are graphed with overlying normative distributions for reference. The pre-post comparisons are used to highlight the improved overall cognitive effects experienced clinically by those finishing the phenotype-driven NF and therapeutic regimen.

Discussion

The dramatic improvement in IQ, memory, and other factors are demonstrated in this group of addiction clients. The incidence of two phcnotypical divergence patterns in the addiction population is noted and suggests two very different approaches. The overarou- sal factor drives one subset of clients in addiction. and the cingulate based phcnotypical divergence pattern drives the other. The use of the phenotype rather than the behavioral diagnosis helps select the appropriate intervention, thus allowing the dramatic improvement seen in these clinical outcomes.

Neurological Aspects of the Tomatis Audio-Psycho-Phonology (APP) as Deduced from QEEG Brain Mapping and Auditory Evoked Potentials (AEP)

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Introduction

The sounds provided in the Tomatis APP Listening therapy cause neurophysiology] stimulation. The physiological stimulation is due to the movements of the ossicles and of the membranes, that is, the eardrum and the oval and circular membranes, and thereby training the antagonistic muscles of the middle ear. The neurological stimulation besides the brain concerns also the hearing, the equilibrium, the vagus nerve, and the recurrent nerves. The recurrent nerve for the left ear has a longer pathway to the larynx than for the right ear. which, combined with the localization of the Broca motor center of speech only in the left hemisphere, results in a retardation of speech by about 0.03 s when the feedback is dominated by the left ear (Tomatis, 1991). This fact and the dominance of the left hemisphere for logics, abstract thinking, language, reading, writing, and calculus stimulated Tomatis to emphasize training of the right ear. The neural stimulation by sound of all organs and muscles of the body is largely accomplished by means of the vagus nerve, which branches from the eardrum and from the outer hearing channel via the spinal marrow to all those peripheries in the body. In general, changes due to the therapy are well visible in the measured QEEG-brain maps and in the auditory evoked potentials (AEPs). They can be correlated with changes in the Listening tests and with the observed improvements in the problems of the individual participants.

In recent years, auditory evoked response techniques have been utilized to objectively assess integrity of the central auditory system in children with learning disabilities, autism, language and attention deficit disorders (Van den Bergh, 1998). Many hundreds of individuals have been treated in this way at the Atlantis institute. At the conference the method is illustrated by the treatment of a man. called Eugen, who suffered a severe stroke, with lack of speech and bad walking.

Method

Eugen has received the Listening Therapy at the Atlantis Institute over years, with 424 30-min sessions and eight intermissions of 2 to 9 months. The quantitative electroencephalography (QEEG) and AEP data were taken with the Sirius, ESAOTE BTOMED1CA equipment, along with the Listening tests (audiograms) before, during, and after the Tomatis APP therapy. The QEEG data are processed quantitatively, in contrast to the classical EEG, as to reconstruct a map of responses over the brain surface, called the brain map. AEPs are measured at the Atlantis Institute, with 19 electrodes on the skull using the International System of Electrode Placement. Auditory clicks or tones are presented mostly into the left ear and the measurements are registered (Van den Bergh. 1998). With the cognitive auditory potentials, the mental processing mechanisms of the auditory perception (attention mechanisms) are explored. Wearing the headphones. 150 tones are presented to the participant: 120 of them are frequent, "standard" low-pitched and 30 are "rare." high-pitched tones. This test is performed under both the attention (to the rare tones) and nonattention condition. Those cognitive potentials are in many cases disturbed in individuals with cognitive immaturity, attention deficit disorders, and learning disabilities.

Results

Eugen has experienced a significant recovery of his speech and motor system. He only moves somewhat slowly with the right leg. In most other cases learning abilities were improved with better concentration, speech, and communication. Lasting improvements have been reported by several institutes, with an average score of about 80% (see http://www.tomatis.com).

In general our results were verified by- other institutes or doctors, as was the case by, for example, the University Clinic at Giessen & Marburg, Germany, where different diagnostic tools were applied, also including EEG measurements. Placebo groups or shams have been followed at several other institutes (see, e.g., http:// www.tomatis.com and by Tomatis. 1991).

Those investigations all show clearly net effects of the method.

Conclusions

It can be concluded that the Listening tests are replicated by the QEEG-brain- map data, thus independently correlating the results of those tests. In most cases attention and concentration problems were observed during the Listening test by the high and often descending bone conduction results at low frequencies with respect to the air conduction test results. This correlated strongly with large *6* activity frontal and prefrontal and with the absence or weak a activity, mostly occipital, in the corresponding brain maps and with weak N200 and P300 amplitudes in the oddball paradigm AEPs, both indicating little alertness. After the Listening therapy those aspects were improved in the Listening tests, as well as in the brain maps and AEPs. Generally a correlation was also observed in the case of language disorders between the diminished sensitivity in the middle frequency region of about 1000- 3000 Hz in the Listening tests and the diminished activity at the temporal lobes in the brain maps. Therefore Listening tests can be used as reliable evidence to support the results of the Listening therapy as they are replicated by the QEEG data. It may be noticed that several neurological aspects of the Tomatis method are similar to those of the Neurofeedback.

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Developmental Changes in the EEC of People with ADHD: Results from an Initial Investigation

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Introduction

Attention deficit hyperactivity disorder (ADHD) is one of the most common disorders of childhood, and research is finding that as many as 60% of childhood sufferers will continue to have the disorder as adults. Research has further shown that the symptom profile of people with ADHD continues to change as they get older, with the hyperactivity commonly seen in childhood reducing, but the impulsive and inattentive components remaining. In addition to the maturational changes in the core symptoms, the profile of other comorbid problems also changes. The aim of this study was to investigate changes in the EEG from childhood to adulthood.

Methods

Forty participants were initially assessed as children (8-12 years old) and reassessed as adults (22-26 years old), with a clinical interview being performed and an eyes- closed resting EEG being recorded at both assessments. From these assessments, EEG abnormalities in the adult population, and changes in the EEG profiles from child to adult were evaluated.

Results

The results indicated the existence of some EEG power and coherence abnormalities in children with ADHD which continued into adulthood. Differences in the EEG were also evident between those thai outgrew the disorder and those that continued to be symptomatic into adulthood.

Discussion

These results have important implications for our understanding of developmental changes in the disorder, which are discussed in this presentation.

Comparison of the TOVA and IVA in a Clinical Population

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The intake TOVAs and IVAs of 300 clients at an attention deficit hyperactivity disorder (ADHD) clinic were compared to each other and to other intake data (parent and/or self report) to determine the diagnostic strengths and weaknesses of each test. Where ADHD or a related disorder was the focus of treatment, the intake was classified as belonging to one of the following categories, according to presenting problems and client checklists: anxiety. ADHD inattentive type, ADHD Impulsive or Combined Type, oppositional defiant disorder, or Asperger's disorder. The correlations of the TOVA (Visual form) and IVA with client checklists and intake concerns were compared. and the efficiency of the TOVA and IVA in differentiating the diagnostic groups was investigated.

The TOVA was found to be better than the IVA in correctly identifying deviations from the norm for all groups. It was superior to the IVA in identifying inattention, whereas both tests were effective measures for impulsivity. The TOVA showed higher correlations with client checklists than the IVA. Further analysis of the IVA subtests suggests that the stamina variable does not contribute significantly to differentiation of ADHD subtypes. The constancy and focus variables are so highly correlated in this sample, that there is a question about the utility of having one contribute to the response control variable, whereas the other contributes to the attention variable. Analysis of TOVA variables suggests that anxiety and ADHD impulsive/ combined type share a common profile.

ADHD Inattentive type, oppositional defiant disorder, and Asperger's disorder also share a similar profile.

Endophenotypes of ADHD in Children and Adults

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Prevalence of ADHD

Attention deficit hyperactivity disorder (ADHD) represents a psychiatric disorder with a high estimated three to five percent in school-age children *(DSM IV)*, Approximately one half of these children continue to manifest ADHD-associated symptoms in adulthood (Biederman. 2005). In the United States the following prevalences in adults with ADHD are known: 4.7% (Murphy & Barkley, 1996). 4.5% (DuPaul et al., 1997), 4.0% (Heiligenstein et al., 1997). In Switzerland, the estimation ranges from 2% to 4% (Eich. 2006).

Symptoms

The most prominent symptoms are not only attention deficits but also difficulties in executive functions, mostly in impulse control/inhibition and working memory. In addition, an emotional dysregulation is often found. ADHD has been described from many perspectives. I am going to circumscribe only the neurophysiological findings.

Models

There are different explanation models for ADHD. The two most common models are the Maturational Lag Model of ADHD (Kinsbourne. 1973) and the Developmental Deviation Model of ADHD (Chabot & Serfontein, 1996; Clarke et al.. 200ld). The first model assumes that children with ADHD show a delay in maturation of the central nervous system. That means they have not yet reached the appropriate developmental stage according to their age. Their EEGs would be considered normal in younger children. The second model assumes the symptomatology of ADHD to have its origin in a dysfunction of the central nervous system. The EEGs of these children is considered to be abnormal at any age. Another model that can be subsumed under the Developmental Deviation Model of ADHD is the Hypoarousal Model of ADHD (Sattcrfield, Cantwell, & Sattcrfield, 1974). This model assumes that the ADHD symptoms are caused by an underactivation of the cortcx.

Both the Maturational Lag Model of ADHD and the Developmental Deviation Model of ADHD are not sufficient to explain the symptoms of this disorder. The often-seen fact that hyperactivity of ADHD children diminishes with aging and the reduced beta activity normalizes is in line with the first model, whereas attention deficits and increased thcta activity, which can also be found in adults could be explained by the second model. Both models are therefore too simplifying and are not able to explain the very complex processes in ADHD. It is necessary to develop new models.

Eeg-Defined Subtypes: A Multieenter Study

In a wide-organized study across Europe in the frame of Cost B27 an action of the EU (Participation: Norway, Germany, Austria. Italy, Macedonia, Turkey, Switzerland) it will be shown that QEEG and especially ERP combined with new HBl-Database and sLORETA are very good tools for making a contribution 10 ADHD-cndophaenotypes. The neurophysiological tools are combined with neuropsychological testing and many questionnaires and interviews. The sample size will be between 250 and 350 participants from 18 to 50 years of age. There is no larger study in this field across Europe at this time.

Presentation

The presentation shows first results of the already-studied population. The used neurophysiological model shows that the EEG subtypes in adults are nearly the same as in children, but the frequencies of different subtypes differs enormous. The study shows that ADHD in adults is much more driven by dysfunction of anterior cingulate cortcx than from inhibition dysfunction. This explains the wide range of comorbidities in adults. The study aims a more objective diagnoses system and better information lor drug- treatment. neuronal stimulation and help in everyday life.

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ERPs Endopenotypes and Their Application in Neurotherapy

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The presentation reviews recent findings in our laboratory. The first part deals with a methodological approach for assessing brain functions. Theoretical part of this approach is based on our experimental findings of local field potentials and impulse activity of neurons in patients with implanted electrodes as well as on neural net simulations of information processing in the human brain. The theory suggests that the brain is decomposed into basic systems such as sensory, executive, affective, memory systems, and attention networks. Modulation of information ilow in each of the systems is characterized by specific rhythms, whereas stages of information processing in these systems are reflected in specific ERP components. Varying tasks and modalities it is feasible to test functioning of practically all cortical areas of the brain. For a particular patient the choice of the task is defined on the patient's complains and on the basis of neuropsychological impairments in the patient.

The second part deals with practical application of the theoretical concepts in a form

ilie iTBI Reference Database. The normative data includes 19-channel EEG recordings in 1.000 people ages 7 to 89 years. It also includes recordings of 400 attention deficit hyperactivity disorder (ADHD) children and adolescents, as well as numerous recordings in other kind of patients (patients with epilepsy, obsessive compulsive disorder, addiction, depression, whiplash, etc.). A 19- channel EEG was recorded in two resting conditions with eyes open, eyes closed, and four different task conditions, including

reading and two auditor)[1] tasks. To reduce amount of time for preprocessing the data several procedures such as artifact correction, artifact elimination, and spike detection are automated. Absolute amplitude and power spectra, averaged and two-channel coherences, wavelet-transformations and event-related potentials (ERPs) are computed in three different montages off-line and mapped into 2D representations or into 3D images using LORETA technology' (including s-LORF.TA). Comparison with the database consists of computing - scores standardized measures of deviation of individual EEG parameters from the normative data. ERPs are subjected to independent component analysis. Using this methodology, separate components associated with distinctive psychological operations are extracted. Each component is characterized by time dynamics, 2D topography, and LORETA image and represents an endophenotype of the brain functioning. Spatial filters are built up on the basis of these topographies and provide the means to extract the amplitude of each component from the individual ERPs. Comparing these amplitudes with the normative data gives the insights concerning different stages of information processing in the individual under assessment.

In the third part of the presentation, the results of application of the TIB1 database for diagnosis various brain dysfunctions are presented. Finally, the application of the database for constructing protocols of neurofeedback and transcranial Direct Current Stimulation in different brain disorders such as ADHD and stroke patients is presented

The Respective Roles of Bipolar and of Synchrony Training

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The original research by Sterman and Lubar on human participants was conducted with bipolar placement on the sensorimotor strip. The shift toward quantitative EEG-guided training also involved

cal impressions guided a return to "bipolar placement over the past several years. The greater strength of that training is attributed to the stronger role of relative phase. The greater strength also motivated a reward-frequency optimization strategy that took us out of the traditional sensorimotor response (SMR)/bct.a range of frequencies. Data on the distribution of optimum reward frequencies are given on some 250 clients. A common mechanism is postulated for the whole frequency range covered by the clinical data. This is referred to as Resonant Frequency Training in that the responsivity of individuals has the character of a standard resonance curve.

There is a bias in bipolar training toward desynchronization of EEG rhythms. The question was therefore addressed whether synchrony training at the same resonant frequency would have complementary, clinically useful effects. A corresponding frequency optimization strategy disclosed that the synchrony training tended to optimize at the known conical resting frequencies of alpha in the posterior region, SMR (nominally 14 Hz) in the central region, and theta in the frontal region (nominally 7 Hz).

Both types of training may be understood as an appeal to the brain that lies predominantly in the phase domain. The promotion of phase synchrony tends to favor the standard training bands that have been used in the field to date, whereas the differential training tends to optimize very individually depending on the particular nervous system characteristics.

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PROCEEDINGS OF THE 2008 SABA CONFERENCE

Abstracts of Conference Presentations at the 2008 Society for the Advancement of Brain Analysis (SABA) 7th Annual Conference, Sarasota, Florida

The 7th annual conference for the Society for the Advancement of Brain Analysis (SABA) was held in Sarasota, Florida, April 30 to May 3, 2008. This group is an outgrowth of ISNR and quantitative EEG research, and their proceedings have been published in this journal in the past. As its name suggests, this society was founded to advance methodology and practice of brain wave analysis, particularly for use in neurotherapy, and this year's conference focused on an issue of interest to many neurotherapists: assessment of frontal lobe function and the role of LEG operant conditioning in addressing executive dysfunction.

David A. Kaiser, PhD
Editor

Effects of Psychoneurotherapy on Brain Electromagnetic Tomography in Individuals with Major Depressive Disorder

Mario Beauregard, PhD

Recent advances in quantitative electroencephalography (QEEG) and brain-computer interface technology provide unique and powerful tools that may significantly contribute to the development of psychoneurotherapies. The main goal of this study was to test the effect of a QEEG-guided psychoneurotherapy (PNT) on brain electromagnetic tomography in 22 individuals with major depressive disorder (MDD). Based on the results of QEEG analyses, depressed participants were taught during the PNT to modify their negative thoughts and emotional states while learning to reduce high-beta (18 30 Hz) activity in right fronto-temporal/paralimbic regions. Brain changes were measured through standardized low-resolution brain electromagnetic tomography. Following treatment, there was a significant reduction of BDI-I1 scores (/x.001), and 20 out of 27 (74%) participants did not meet the *DSM IV* criteria for MDD. Absolute power of high-beta (18-30Hz) activity showed a significant reduction in the right lateral prefrontal cortex, right orbitofrontal cortex, right insula, right subgenual cingulate cortex, and right anterior temporal pole.

These findings suggest that the PNT used in this study can significantly improve brain activity and reduce depressive symptoms in individuals with MDD.

Functional Homogeneity and Heterogeneity of the Frontal Lobes

Elkhonon Goldberg, PhD

Recent advances in understanding how the prefrontal cortex accounts for the wide variety of abilities categorized as executive function has led to a detailed study of the functional units of the prefrontal cortex. Using studies based on functional imaging technologies and neuropsychological tools, Isummarize both broad and granular subdivisions of the frontal lobes. This summary includes an overview of orbital frontal and dorsolateral roles in executive function. I demonstrate how the full range of executive functions corresponds to the functional heterogeneity of the prefrontal cortex.

The Brainstem and the Frontal Lobes in Attention Deficit Disorder and Memory Loss

Elkhonon Goldberg. PhD

This presentation addresses how traditional approaches to understanding attention deficits and memory disorders that have focused on the subcortex, the mesial temporal lobes, and the cyngulate gyrus are incomplete. My studies and writings have illuminated central roles in altcntional and memory impairments of both the frontal lobes and the brain stem as well as the areas just listed. 1 demonstrate how executive functions controlled by the prefrontal cortex interact with systems responsible for arousal in the brain stem to play as integral a role as the subcortical structures, the cyngulate gyrus, and the hippocampi in understanding attentional and amnestic phenomena.

Periodicity Table

David Kaiser. PhD

Spectral properties are organized into a general framework based on number of signals, frequencies, and other features. The Periodicity Table, as it is called, surveys the wide range of synchronies inherent to EEG activity and connectivity measures. General spectral properties such as number of frequencies, number of sites, and whether phase or magnitude are being evaluated, are represented by dynamic as well as static versions of each property in this table (e.g., eomodula- tion, magnitude asymmetry), and each version is further represented by a mathematical function (e.g., Pearson product moment, coherence function). This table was used to generate the indices known as site-centered comodulation and site-centered coherence. Site-centered comodulation is mean comodulation of all electrode partners (19 pairings minus 1 auto-comparison), an estimate of network traffic or common activity at a site, and site-centered coherence is mean coherence of all electrode partners, a phase-based estimate of network traffic. Posterior site-centered coherence and comodulation were found to increase with age lor frequencies below 30Hz in a database of 101 participants from ages 5 to 35 years. Anterior site-centered comodulation also increased with age for this group. The Periodicity Table was proposed as a means to categorize synchrony manifestations and as a tool for generating new and potentially relevant psychophysiological indices. Furthermore, by contrasting cells within this table, impairments missed by measures in isolation may be revealed by their composite. Three examples of cross-table comparisons are *corticality,* a z score contrast of magnitude consistency lo phase consistency; *focality,* activity compared to connectivity measures; and *cordance*, a comparison of relative to absolute power (Leuchter et al., 1994).

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Client History, QEEG and Neuropsychological Assessment: When the Data Speak Together

William A. Lambos. PhD

1 demonstrate how the clinical interview and relevant neuropsychological testing serve as independent and convergent sources of data in producing a complete and accurate evaluation of a client's condition. Client history and neuropsychological abnormalities help disambiguate EEG findings, further strengthening the instrumental power of quantitative analysis of EEG. Tendency for practitioners of EEG biofeedback to rely solely on QEEG data, or less, in developing treatment approaches has substantial limitations. I argue that for neurotherapy to gain wider acceptance by both prospective clients and other practitioners, an integrated approach that incorporates personal, neuropsychological, and psychophysiological data should become a standard of practice.

(MRI Correlates of Neurofeedback Treatment for Attention and Learning Disorders

Johanne Levesque, PhD

Electroencephalogram (EEG) biofeedback, also known as neurofeedback, has been used as a promising alternative treatment for patients with attention deficit/hyperactivity disorder (AD/HD) since the beginning of the 1970s. This technique has also been utilized in the treatment of learning disabilities (LD). Over the years, many different EEG biofeedback protocols for AD/HD and LD have been developed. Single-channel protocols and interhemispheric protocols are widely used with notable success. Recently, studies have shown that self-regulation of slow cortical potentials for children with AD/HD can also be "possibly efficacious" in alleviating symptoms of AD/HD. The objective of this presentation is to provide a comprehensive review of the literature with regard to cerebral, cognitive, and behavioral changes induced by neurofeedback in children with AD/HD or LD.

What I Have Learned About ADD: QEEG and Neurofeedback Studies

Joel Lubar, PhD

I review the history of studies regarding quantitative EEG, LORETA, and neurofeedback as they pertain to attention deficit/ hyperactivity disorder (AD/HD). I also show how work done to date has fallen short of establishing a coherent framework for understanding the many symptoms and subtypes classified under the label AD/HD. I also offer suggestions for a unifying paradigm of research using neurofeedback, research modes for controlled and clinical studies, and a summary of our research in the area of ADD/HD and some new work- using LORETA neurofeedback.

A Remarkable Neurofeedback Outcome with Severe Brain Damage and Seizures

Demse Malkowitz, MD

Neuroplasticity is the intrinsic ability of the brain to change itself in response to input, resulting in learning and formation of related functional neural networks. In the case of brain injury- or dysfunction, neuroplasticity allows for the reintegration and formation of neural networks. This process can take place with relevant stimulation and learning experiences over time. However, it appears that this can be significantly enhanced, in terms of extent of recovery and time to recovery, when the individual receives an appropriate neuro-rehabilitation program. Quantitative EEG (QF.EG)-neurotherapy, or neurofeedback, appears to be a powerful tool for neuro-rehabilitation in patients with a number of neurological, psychiatric, and cognitive disorders. QEEG-neurotherapy applies operant conditioning principles, rewarding and reinforcing desirable self- regulated EEG activity and inhibiting or suppressing undesirable activity. The changes in EEG toward normalcy appear to reflect changes in underlying neurophysiology, with reintegration of neural circuits and networks. Our intensive QEEG- Neurofeedback protocol to treat refractory seizures in patients with acquired epilepsy and neurological deficit from traumatic brain injury yielded a remarkable recovery both in terms of extent of recover)' and time to recovery, even 10 years after the brain injury, despite failure of many other therapies. QEEG-Neurofeedback appears to work through utilizing neuroplasticity, retraining the brain, building neural circuits and networks. This therapy is self-directed, is noninvasive. and lacks any significant adverse effects. Maximizing these therapeutic effects will require a search for the most effective diagnostic and treatment protocols. Appropriate standardized QEEG-Neurotherapy protocols must be sought and adhered to. The future of QEEG-Neurofeedback thus lies in cooperative scientific research and accountability.

Methodology and Clinical Applications Relevant to Frontal I.obe Issues

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Functional connectivity is a central principle of brain maturation and it may be assessed partly by coherence and comodulation functions. We examined coherence and comodulation of low and moderate frequencies and found that there was an increase in lhcsc indices with age at most sites in a sample of 101 children and adults. Of interest were frequencies modulated by thalamocortical and corticothalamic collaboration (4-30 Hz). Site-centercd comodulation increased consistently with age at all sites, whereas site-cen- tered coherence only increased with age at posterior sites. Site-centered comodulation was found to be a better index of frontal lobe maturation than coherence. No significant age-connectivity relationship was found for anterior sites during childhood but significant ones emerged during adulthood, a finding that parallels callosal myelination between frontal lobes. For both measures, it would be useful to investigate whether age- based functional connectivity increases evenly throughout the lifespan or whether coupling rates asymptote or accelerate during later years. Assessment of frontal lobe connectivity might identify functional impairment prior to clear-cut behavioral or cognitive symptoms of executive dysfunction.

The Work of Neurologist Wen Qing Wu with Neurofeedback and Seizures

Lynda Thompson, PhD

Dr. Wu Wenqing, Friendship Hospital & Capital Medical University of Beijing, has treated about 100 patients with seizure disorder using neurofeedback (NFB). He is presently assisting other doctors and hospitals to set up neurofeedback units for the treatment of seizures and other disorders by raising sensorimotor response. We were honored to have him study at our center in Toronto for 6 months in 2007. In 2006 the Chinese national television network asked him to present a patient. We show the DVD that played on Chinese television. The woman chosen for this demonstration was 23 years of age. Before NFB training she experienced approximately 35 grand- mal seizures a day. She had been treated with many different combinations of medications and had surgery for the seizure disorder twice before NFB was attempted by Dr. Wu. Enuresis accompanied each seizure episode. Two years after NFB training, in 2007, she had only one seizure a day, and it was without enuresis. Now, in 2008, she has only one seizure every 1 to 2 days. She still takes two kinds of antiepileptic drugs, but we understand that the dosage of medications is substantially less than before NFB training. Dr. Wu concluded in his latest e-mail to us that "neurofeedback influenced her seizure, and had a long term effect."

It is both a dramatic and a convincing film, and we are very thankful that Dr. Wu has given us permission to show his work to you.