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Effects of Spatial Specific Neurofeedback Training in Anterior Cingulate Cortex

Rex L. Cannon
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Rex L. Cannon entitled "Effects of Spatial Specific Neurofeedback Training in Anterior Cingulate Cortex." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Experimental Psychology.

Joel F. Lubar, Major Professor

We have read this thesis and recommend its acceptance:

Lowell Gaertner, Deborah Baldwin

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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EFFECTS OF SPATIAL SPECIFIC NEUROFEEDBACK TRAINING IN ANTERIOR CINGULATE CORTEX

A Thesis presented for Master of Arts Degree

University of Tennessee, Knoxville

Rex L Cannon
May 2007

Life is not about reaching the top

It is about the quality of the climb

For Miranda, Avery and Jack

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Abstract

This study examines the efficacy of a recently developed methodology of spatial-specific neurofeedback training in the cognitive division of the anterior cingulate gyrus and describes its relationship with cortical regions known to be involved in executive functions and attentional processes. This study was conducted with eight non-clinical students, four male and four female, with a mean age of twenty-two. Exclusion criteria consisted of prior head trauma, neurological or psychiatric disorders, medications and recent drug or alcohol use. Learning occurred in the ACcd at significant levels over sessions and in the anterior regions that receive projections from the AC. There appears to be a multi-dimensional executive circuit that increases in the same frequency in apparent synchrony with the AC and it may be possible to activate this circuit by training one cortical region using LNFB.

Preface

The human brain is the most complex system known to the human experience. For centuries philosophers and researchers have attempted to conceptualize how this organ functions. As technology increases, so does our understanding of the 'where and what' of brain function. The techniques for analyzing brain activity stem from numerous branches of study; including, physics, mathematics, psychology, philosophy, physiology, anatomy, computer science and biology. The need for a holistic approach is indispensable, for it is suggested that the nature of the universe is somehow analogous to the nature of the brain. I tend to visualize the brain with the concept of a cityscape. If we look at a large city from a panoramic view we see a vast number of columns containing individual units that are interconnected by tunnels, caverns, rivers, wires and cables delivering vital chemicals, and electrical power to specific sites for specific purposes. If a single light is turned on in one particular site, the effects on the entire system are of immense interest. Great concern is desirable when investigating the human brain. As with most sciences there is a tendency toward a reductionistic viewpoint, viz. that one particular region or one cluster of neurons is responsible for any given task or function. I do not perceive the brain as being this unsophisticated; it is in verity the greatest mystery in the universe.

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Chapter 1: Introduction

The anterior cingulate gyrus (AC) is a subject of intense interest and has been the focus of numerous studies over the past decade. Studies report involvement of the AC during a wide variety of cognitive, mnemonic and emotional tasks (Cabeza and Nyberg, 2000; Cannon, Lubar, Congedo, Thornton, Wilson, 2005; Markela-Lerenc, Ille, Kaiser, Fiedler, Mundt, & Weisbrod, 2004; Devinsky, Morrell & Vogt, 1995). In a review, Devinsky, et al., (1995) sum the processes of the AC as; crucial in initiation, motivation, and goal directed behaviors, emotion and motor functions, attention, direct control of skeletal and visceromotor systems, response selection, cognitively demanding processing devoid of movement and possible reclamation from short term memory. The AC contains both cognitive and affective areas. The cognitive division consists of Brodmann areas 24 and 32, while the affective division consists of Brodmann areas 25, 33 and rostral area 24. This affective region is reported to be involved with regulating endocrine and autonomic functions, as well as conditioned emotional learning, vocal expression of internal states and emotional valence concerning external and internal stimuli (for review see Devinsky et, al., 1995). The AC sends afferents to the amygdala and thalamo-cortical structures that possibly influence internal states associated with emotions. In this respect, it is considered part of the rostral limbic system, which includes the ventral striatum, the amygdala, periaquaductal grey, anterior insular cortex and the dorsolateral prefrontal and orbitofrontal cortices. Seizure disorders involving the AC are reported to result in altered levels of attention and consciousness (Devinsky, et al. 1995).

Attentional processes are probably the most investigated function of the AC (Pardo, Pardo, Janer, & Raichle, 1990; Bench, Frith, Graby, Friston, Paulesu,

Frackowiak, & Dolant, 1993; Posner & Petersen, 1990). Activation of the prefrontal cortex (PFC), AC, bilateral parietal cortex and occipital areas is reported in functional magnetic resonance imaging (fMRI) experiments involving sustained attention and counting (Ortuño, Ojeda, Arbizu, Lopez, Marti-Climent, Peñuelas, & Cervera, 2001). Studies report significant activation of the supplementary motor area (SMA) during attentional tasks and suggest that the SMA, dorsolateral PFC, inferior parietal lobes and the AC would be related to attentional effort as a general factor (Carr, 1992). Posner and Peterson (1990) suggest an anterior attention system that involves the AC and portions of the SMA and a posterior attention system that involves parietal regions and sub-cortical structures. Positron Emission Tomography (PET) studies report bilateral metabolic reductions in the hippocampal formation, thalamus, AC and frontal basal cortex, which support the contribution of the AC in a network involving memory (Fazio, Perani, Gilardi, Colombo, Cappa, & Vallar, 1992). One prominent theory proposes that the AC detects the need for executive control and signals the PFC to execute the control (Markela-Lerenc et al., 2004). Executive functions are suggested to be an enveloping process that involves all cognitive processes associated with goal completion, anticipation, goal selection, planning, and initiation of activity, self-regulation, monitoring and use of feedback (Sohlberg & Mateer, 1989). This suggests that executive functions are not only instrumental in cognitive processes but also crucial in attentional effort and maintenance.

It has been demonstrated that humans can acquire a certain degree of control over the electrical activity of their own AC, coupling the low-resolution electromagnetic tomography (LORETA) with the neurofeedback technique (Congedo, 2003; Congedo,

Lubar & Joffe, 2004), yielding a non-invasive technique known as LORETA Neurofeedback (LNFB). In these preliminary studies, only the changes in the AC have been evaluated. However, it has been established that executive processes are mediated by the frontal lobes and in particular by the projections from the AC to the prefrontal and parietal cortices (Kondo, Morishita, Osaka, Osaka, Fukuyama, et al., 2003; Heyder, Suchan, & Daum, 2004; Duncan & Owen, 2000), namely, the bilateral dorsolateral prefrontal cortex, left (LPFC) and right (RPFC), the right post-central gyrus (RPCG), the bilateral supramarginal gyri (RSMG, LSMG), and the cuneus. Hence, based upon current information, we sought to define the correlational structure of cortical regions directly involved in the self-regulation of the electrical activity of the AC. Particularly; our study investigates the efficacy of the LNFB training within the cognitive division of the AC (ACcd) and its effect in these connected regions. Following Congedo, Lubar and Joffe (2004) we aimed at improving attentional processes, thus we trained individuals to increase 14-18 Hz (low-beta) power activity in a seven-voxel cluster defining the ACcd, within the Brodmann Area (BA) 32 with center coordinates at X = -3, Y = 31, Z = 29. The definition of the region of interest (ROI) followed indications of Devinsky et al. (1995). The effect of the training was assessed by means of a number of pre-post and learning electrophysiological measures; also the efficacy of the training was assessed by means of pre-post training psychometric testing using subtests of the Weschler Adult Intelligence Scale – Third Edition (WAIS-III).

Chapter 2: A Brief Introduction to Neurofeedback and EEG

Quantitative electroencephalogram is a digitized representation of the analog EEG signal. EEG oscilloscope tracings were historically printed on paper; however, with the advent of computers these waveforms can be amassed and scrutinized on computers. EEG is routinely recorded from 19 locations with either a ground reference, linked ear reference or both. This study exploits both. There are usually two general classes of measurements utilized in EEG, first, the activity at each of the electrodes at a specific frequency; this involves magnitude, relative power, peak amplitude, peak frequency, symmetry and spectral power; second, the connectivity between electrodes involves both coherence and phase measurements. This information gives passable approximation of measurement of waveforms going from one peak to the next or more appropriately, cycles per second in the neuronal cells in 3mm of cortical matter under the skull (Demos, 2005; Gomez & Thatcher, 2001). Neurofeedback is an operant conditioning method, in which participants learn to control their own EEG activity. This is done by placing electrodes on the head and obtaining the electrical signal, the signal is then processed through a computer interface and set to covary with auditory or visual stimuli according to the criteria set within any training protocol.

Neurofeedback techniques have been utilized in clinical and research settings for treatment of epilepsy (Sterman, 2000, 2001), attentional disorders (Lubar and Lubar, 1999), alcoholism and posttraumatic stress disorders (Peniston and Kulkosky, 1989, 1990, 1991), and continue to be a focal point of development for possible treatments for psychological disorders as well as exploration of brain function. A recent fMRI study reports neurofeedback techniques initiating blood oxygenated level dependent (BOLD)

changes in the AC, caudate and substantia nigra in AD/HD children (Levesque, Beauregard & Mensour, 2006). LNFB and spatial-specific training offer the possibility to influence regions deep in the medial temporal lobes, limbic regions and regions at the base of the brain, such as the insular cortex, parahippocampal, lingual, fusiform, and orbital-frontal gyri, which contribution to surface EEG is poor. As compared to the effects of traditional neurofeedback, which is spatially unspecific (Congedo, 2003), LNFB may target a relatively small neuronal population. For this study we will focus on those regions of the cortex that change in low-beta activity as a possible function of or in synchrony with the AC over approximately 30 sessions of LNFB training. To date, no study has investigated the simultaneous changes that occur in several regions of the cortex as a consequence of either traditional or spatial-specific neurofeedback training.

LORETA (Pascual-Marqui, 1995, 1999; Pascual-Marqui, Michel, & Lehmann, 1994; Pascual-Marqui, 2002) was used to estimate in real-time current density in the ACcd. In conventional neurofeedback, electroencephalographic (EEG) activity is recorded at a particular scalp location. The physiological measurements are extrapolated from the signal and converted into auditory stimuli or visual objects that animatedly co-vary with the magnitude of a specified brain frequency or frequency band. Similarly, LNFB correlates the physiological signal with a continuous feedback signal; however, the physiological signal is defined as the current density in a specified ROI. This allows the continuous feedback signal to become a function of the intracranial current density and to covary with it. LORETA is a widespread linear, discrete, instantaneous, full-volume inverse solution for brain electromagnetic measurements (for review see Pascual-Marqui et *al*., 2002a, 2002b). Whereas EEG is a measure of electric potential variations,

LORETA estimates the current density that results in the potential divergence on the scalp. Using realistic electrode coordinates (Towle et al., 1993) for a three-concentric-shell spherical head model co-registered on a standardized MRI atlas (Talairach, & Tournoux, 1988); anatomical labeling of the reconstructed neo-cortical volume is possible (Lancaster et al., 1997, 2000). We used the three-shell concentric spherical head model implementation made available from the Key Institute for Brain-Mind Research, Zurich, Switzerland. In this implementation, the current density is mapped for 2394 voxels of dimension 7x7x7 mm covering the entire neocortex plus the AC and hippocampus.

Chapter 3: Methodology and Equipment

3:1 Participants

This study was accomplished with eight participants, four male and four female non-clinical students at the University of Tennessee, Knoxville, with a mean age of 22, standard deviation 1.92 and range 20-26. Seven of the participants were right handed and one was ambidextrous. All participants read and signed and agreed to an informed consent to protocol approved by the University of Tennessee Institutional Review Board. Participants received extra course credit for participating in this study. Exclusionary criteria for participation included previous head trauma, history of seizures, recent drug or alcohol use and any previous psychiatric diagnosis.

3:2 Procedures

Participants were prepared for EEG recording using a measure of the distance between the nasion and inion to determine the appropriate cap size for recording (Electrocap, Inc; Blom & Anneveldt, 1982). The head was measured and marked prior to each session to maintain consistency. The ears and forehead were cleaned for recording with a mild abrasive gel to remove any oil and dirt from the skin. After fitting the caps, each electrode site was injected with electrogel and prepared so that impedances between individual electrodes and each ear were < 6 KΩ. The LNFB training was conducted using the 19-leads standard international 10/20 system (FP1, FP2, F3, F4, Fz, F7, F8, C3, C4, Cz, T3, T4, T5, T6, P3, P4, Pz, O1 and O2). The data was collected and stored with a band pass set at 0.5–64.0 Hz at a rate of 256 samples per second. All recordings and sessions were carried out in a comfortably lit, sound attenuated room in the Neuropsychology and Brain Research Laboratory at the University of Tennessee,

Knoxville. Lighting and temperature were held constant for the duration of the experiment. Each session required approximately forty minutes to complete.

3:3 Neurofeedback Protocol

Thirty-three training sessions composed of four four-minute rounds were conducted three times per week. Following Congedo, Lubar and Joffe (2004) we aimed at improving attentional processes, thus we trained individuals to increase 14 -18 Hz (low-beta) power activity in a seven-voxel cluster defining the ACcd, within the Brodmann Area (BA) 32 with center coordinates at X = -3, Y = 31, Z = 29. In a preliminary session, the participants were instructed to control tongue and eye movements, eye-blinks, and muscle activity from forehead, neck, and jaws. This enabled the subjects to minimize the production of extra-cranial artifacts (EMG, EOG, etc.) during the sessions. At the end of the preliminary session, they were informed of the inhibitory and reward aspects of the training. Standardized thresholds were then set and maintained for each participant. Table 1 (see appendix I for all tables and figures) shows inhibit and reward criteria for this training protocol. Table 2 shows the setting for inhibits for electrode combinations and reward criteria. The participants were provided visual and auditory feedback and points were achieved when they were able to simultaneously lower extra-cranial artifacts and enhance current density activity in the region of interest.

Maintaining the condition for 0.75 seconds achieved one point. Following Congedo, Lubar and Joffe (2004) we made use of both auditory and visual feedback. The auditory stimuli provided both positive and negative reinforcement, an unpleasant splat sound when the conditions were not met and a pleasant tone when they were. Similarly, the visual stimuli were activated when the criteria were being met, e.g., a car or a

spaceship driving faster and straighter. Alternatively, a slower car, driving in the wrong lane or the spaceship flying slow and crooked occurred when the criteria were not being met. The score for meeting the criteria was also seen by the participants in a small window of the game screen.

3:4 Data Collection

Three-minute eyes opened and eyes closed baselines were collected before and after the neurofeedback training for pre-post brain imaging comparison. Likewise, three-minute eyes opened baseline recordings were collected before and after each session. In contrast with studies on traditional neurofeedback, the whole-head EEG data was continuously stored during the sessions. In addition, the participants in this study provided a written record of their experience, strategies, and mental processes employed to obtain points for each session during this training.

3:5 Data Pre-Processing

All EEG data were processed with particular attention given to the frontal and temporal leads. All episodic eye blinks, eye movements, teeth clenching, jaw tension, body movements and possible EKG (Electrocardiogram) were removed from the EEG stream. Fourier cross-spectral matrices were computed and averaged over 75% overlapping four-second artifact-free epochs, which resulted in one cross-spectral matrix for each subject and for each discrete frequency.

3:6 Psychometric Pre Training Measures

We administered the Weschler Adult Intelligence Scale – Third Edition (WAIS-III) for a pre-training measure. The mean Full Scale Index Score (FSIQ) is 124, range (118 – 139), SD = 6.79. We selected the Working Memory Index (WMI) and Processing

Speed Index (PSI) scores for post training comparison. The mean pre WMI score is 118, range (94 –141), SD = 5.81. The mean pre PSI score is 107, range (88 – 120), SD = 3.93. The WMI score consists of the sum of scaled scores in the Arithmetic (A), Digit Span (DS) and Letter-number sequencing (LN) subtests. The PSI score consists of the sum of scaled scores in Digit-symbol Coding (CD) and Symbol Search (SS). We used these combinations of subtest scores following indication of Sattler (2001).

3:7 Data Statistical Analysis

In this study, we focus on seven ROIs, of which one is the *active ROI* (ACcd) and the other six, the *secondary ROIs,* have been found to be functionally associated to it. Table 3 lists the name of the ROIs, the number of voxels composing it; the Talairach coordinates of all voxels within the ROI and its Brodmann area/anatomical labeling.

The data analysis for this study included four stages. First (stage I), to assess the covariance of the ROIs within the linear increase over session and rounds we conducted an ANOVA. The within-subjects experimental design required an accommodation for the violation of the assumption of independent observations, which is typical of neurofeedback since each session is dependent on the previous sessions as are the rounds within each session. We utilized the Complex Linear Mixed Models method (Shaalje, McBride & Fellingham, 2002; Schabenberger & Pierce, 2002) PROC MIXED in SAS, version 9.1. We used the REML (Residual Maximum Likelihood) estimation method (Kackar & Harville 1984; Rao, 1972) for the Prasad-Rao-Jeske-Kackar-Harville (1990) fixed effects model and the Kenward-Roger (1997) adjustment for degrees of freedom. The experiment wise error rate was maintained at 0.05 using Tukey methodology (Westfall, et al, 1999).

Second (stage II), after averaging across the four rounds within each session, we conducted a Pearson correlation analysis to assess a linear upward or downward trend of the current density changes in the seven ROIs of table 3. Threshold of significance for the correlation coefficients *r* was set to abs(*r*) =0.01. This stage was conceived to individuate those ROIs in which current density amplitude tends to increase (positive correlation) or decrease (negative correlation) as a function of the neurofeedback learning process.

Third (stage III), in order to assess the electrophysiological differences between pre and post training baselines over the entire neo-cortex, we conducted all voxel-by-voxel *t*-tests setting the threshold to abs (*t*) = 4.0.

Finally (stage IV), we analyzed the pre and post psychometric scores using an ANOVA. This analysis tests whether the spatial-specific training of low-beta activity in the ACcd results in a positive influence in cognitive performance related to attention and executive processes in normal subjects.

Chapter 4: Experiment Results

4:1 Learning Curves

Table 4 shows the results of the mixed model analysis of the learning curves. Our model defines the variance-covariance and mean parameters for the fixed effects of each ROI with the ACcd, i.e. the main effect of learning in each region for rounds, sessions and rounds by sessions. There is a significant learning effect in the ACcd, LPFC, RPFC, RPCG and RSMG. The cuneus and LSMG show no learning effect in the trained frequency. The session, round and session by round effects are not of significance; in this model this is an expected result since these items are defined as a covariance structure rather than a main effect within the model.

4:2 Correlations

Table 5 shows the degree to which neuronal populations in the extracted anterior regions of interest share a relationship with each other. The relationship between the ACcd, bilateral dorsolateral prefrontal cortex and right post-central gyrus is significant. The anterior and posterior regions do not appear to be correlated. It is interesting that the left supramarginal gyrus is negatively correlated with the cuneus while the right is positive.

In the three following subsections we detail results of the learning curves in the ACcd, anterior regions and posterior regions.

4:2:1 Anterior Cingulate Gyrus

Figure 1A shows the within session group results at the ACcd. The plot is obtained averaging current density across all subjects and sessions. On the average, rounds one and two decrease within sessions as compared to the beginning baseline (BB).

Then there is a linear increase in current density in rounds three and four and the ending baseline (EB). Figure 1B shows the average current density in the ACcd for all subjects for all rounds combined over sessions. In this particular training, the current density in neuronal populations within the ACcd shows an increase over sessions at significant levels.

4:2:2 Anterior Regions

Figure 1C shows the average current density in the extracted anterior regions of the cortex over sessions. The cluster of three voxels in the LPFC for all subjects averaged a linear increase significantly higher than the current density produced in the ACcd. The cluster of four voxels in the right dorsolateral prefrontal cortex increases in current density at an average rate higher than the ACcd for all rounds combined over sessions; however, lower than the LPFC in the same respect. The current density in the five-voxel cluster in the RPCG also increases over sessions. The activity in this cluster correlates significantly with the right dorsolateral prefrontal cortex (.749). Note that the frontal and parietal lobes are typically divided into two functional areas, immediately rostral and caudal to the Rolandic fissure, the anterior region including BA 1, 2, 3, and the posterior area that includes BA 5 and 7.

4:2:3 Posterior Regions

The supramarginal gyri, along with the angular gyrus are referred to as the inferior parietal lobes, and are suggested being involved with the cuneus in higher order visual processing. Figure 1D shows the average current density in the posterior regions of the cortex for all training rounds combined over sessions. The cluster of six voxels in the right supramarginal gyrus decreases in the trained frequency over sessions, as does the

five-voxel cluster in the left supramarginal gyrus and the seven-voxel cluster in the cuneus.

4:3 Pre-Post Comparisons

Pre and Post eyes-closed and eyes-opened baseline recordings were evaluated for significance. The resulting images plot only the significant t-values for the comparison, with the t-value maximum threshold set at > 4.0. Figure 2A shows the significant differences between pre and post eyes closed baselines pointing at the ACcd. The maximum increase is in the right inferior temporal region, while the maximum decrease is in the left parietal and temporal cortices. Also of significant increase are the superior frontal gyrus, the orbital, rectal and medial frontal gyri, the right post central gyrus and temporal regions. Figure 2B shows the significant increase in the ACcd in an eyes opened recording. The maximum increase assigned by LORETA is in the right inferior temporal region and the maximum decrease is in the left parietal and temporal cortices, right parietal and occipital regions, including the cuneus and posterior cingulate. Of particular interest is the increased activation in the right inferior temporal cortex and how it relates to the region of interest, ventral portions of the AC and its role in visual processing.

4:4 Psychometric Post Measures

The post psychometric measures for all subjects were taken at session 30, which was one week prior to the end of the spring semester. We opted for this time to avoid the possible confounding effects of the stress and anxiety associated with finals. Table 6 shows the results for the analysis of the pre and post obtained subtests; WMI and PSI scores. Included in the table are the pre and post subtest scaled scores, the mean, standard deviation, 95% confidence intervals (lower – upper), the difference between the pre and

post subtests, the degrees of freedom, the F value and the probability of F. In psychometric testing, there is the consideration of practice effect and test-retest reliability. For the WAIS-III, the test-retest gains and losses for the age group 16-29 are reported as: Coding (+1.2), $p < .001$, Arithmetic (+0.6), $p < .001$, Digit Span (+0.5), $p < .05$, Symbol Search (+1.0), $p < .001$, Letter-Number Sequencing (+0.1), $p > 0.05$, Working Memory Index (+2.9), $p < .01$, Processing Speed Index (+6.0), $p < .001$ (Sattler, 2001). The differences between the pre and post measure scores are significantly higher in our group than in the test-retest group in all subtests, except in the Arithmetic and Letter-Number sequencing scores, where differences still are in the desired direction.

4:5 Subjective Reports

In an attempt to control for the subjective state of the individual during the task, which is seldom done in brain imaging studies, we utilized this process in order to maintain a record of the mental activities the subjects engaged in during the LNFB sessions. The written reports included attention to muscle and eye movement, the visual characteristics of the game, the pleasant tone and making the unpleasant splat stop, working memory, long and short-term memory, counting, mental verbalization (talking to the game, themselves or singing songs), thoughts of daily stresses, frustration relating to performance, sexual imagery and breathing or visualization techniques. Figure 2C shows the results of these reports. The majority of participant responses report mnemonic and attentional processes for maintenance of activity in the AC. Approximately 85 percent of the reports refer to working memory processes and 82 percent report attentional processes. The AC and the associated ROIs are known to be involved in these specific processes and further study is needed to confirm these results.

Chapter 5: Discussion and Conclusion

We sought to determine the efficacy of LNFB in training non-clinical subjects to activate a limbic region and to describe the nature of the relationship between these seven groups of neuronal populations within cortical regions that are identified in the literature as being active in tasks involving attention, mnemonic, cognitive and executive processes (Cabeza, Dolcos, Prince, Rice, Weissman, & Nyberg, 2000; Carr, 1992; Heyder, et al, 2004; Kondo, et al, 2003; Ortuño, et al, 2001; Tzourio, et al, 1997). The obtained data suggest that LNFB may be an efficacious methodology for neurofeedback training in the AC. The linear measures of learning are significant in the AC and the anterior and parietal regions of interest. There are significant, positive linear associations between neuronal populations within the ACcd, LPFC, RPFC and RPCG, which offers further support to the specificity of these regions in executive functions; moreover, it supports the suggested domination of a fronto-parietal right hemispheric network in attentional processes (Garavan, et al, 1999). The regions of interest in the dorsolateral prefrontal cortex (RPFC, LPFC) and the right post central gyrus (RPCG) show significant learning effects relative to the AC. Of considerable interest is how these regions improve to a greater degree than the AC in the trained frequency. This increase is possibly attributed to the AC's centralization to the aforementioned fronto-parietal network and its possible regulation of tasks involving selective attention, concentration, motor control, spatial information, controlling muscle activity, attention to surroundings, the game itself, visual and auditory stimuli, and using cognition, attention and mnemonic, i.e., executive processes as goal directed behaviors.

It is suggested that several independent circuits operate to control attention, cognition, memory and executive functions. Alternatively, executive functions are suggested to include all the processes of attention, cognition, memory, initiation and drive, response inhibition, task persistence, organization, generative thinking and awareness (Sohlberg and Mateer, 1989). It is our speculation that the data obtained in this study offers support to this second suggestion, and maps a plausible circuit of executive function involving these *ROIs* and the AC. If the AC is indeed a gating mechanism, as suggested by Pizzagalli, et *al* (2003), then sustained activity in this particular cluster of voxels may represent a ceiling effect and initiate facilitation of cortical areas that are known to receive projections from the AC. This appears to be reinforced by the differences in learning curves achieved in the secondary *ROIs*. The AC remains a focal point for study, due in part to its location in the brain and its projections throughout the cortex and to sub-cortical structures. The data obtained in this study suggests that this circuit is activated and developed in the trained frequency over sessions and the individuals in this study learned to activate this circuit through feedback about the electrical activity of their own ACcd.

The posterior parietal regions of interest (LSMG, RSMG and Cuneus) appear less sensitive to the influence of the AC in the trained frequency. They do, however, increase in higher beta activity 20 – 32 Hz (Cannon, et al, 2006), which is possibly attributed to the focus on the auditory and visual aspects of the training and reported techniques utilized by the subjects to obtain points. The differences between these posterior and anterior *ROI*s offer the possibility of frequency specific activity, rather than two separate systems. The psychometric results offer support to the increase of higher beta activity in

the occipital and higher order visual processing regions. The increase in PSI scores suggests that the neurofeedback training positively influenced processes involving visual motor coordination, attention, concentration, visual acuity, visual scanning and tracking and short-term memory for learning new tasks. Similarly, the increased WMI index score suggests a positive influence in short-term memory, auditory memory and attentional processes, which would be aided by the LPFC and ACcd. The results imply that LNFB training positively influenced both working memory and processing speed tasks.

Two limitations of the neurofeedback method based on inverse solutions as implemented in this research should be kept in mind. First, the actual region trained does not correspond exactly to the ACcd due to the approximated head model we employed. Second, the spatial specificity of LORETA with 19 electrodes is in the order of several cm^3, therefore the activity of brain regions close to the regions we monitored could have influenced the results. The first limitation can be resolved by constructing realistic head models based on magnetic resonance imaging information. The second has been the object of a recent investigation (Congedo, 2006).

It would have been beneficial to this study to include a control group for excluding confounding effects and this is planned for our future research. Our future research will also involve training individuals to activate the clusters of neuronal populations in the dorsolateral prefrontal cortex to be compared to the AC.

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APPENDICES

Appendix I

Tables and Figures

Table 1: Shows inhibit and reward criteria for the training protocol.

	Inhibits/Reward	Action
(A)	Electro-oculogram (EOG) < 15.0 (Microvolts)	SUPPRESS
(B)	Electromyogram (EMG) < 6.0 (Microvolts)	SUPPRESS
(C)	Region of Interest (ROI) > 5.0 (Current Density)	ENHANCE

Table 2: Shows the specific sites for inhibit and frequency for reward

	Electrode Inhibits and Reward at ROI
(A)	decrease 1 – 3 Hz activity in a linear combination of six frontal channels, FP1, FP2, F3, F4, F7, F8
(B)	decrease 35 – 55 Hz activity in a linear combination of six temporal and occipital channels, T3, T4, T5, T6, O1, and O2
(C)	increase current source density (14 – 18 Hz) in the ROI.

Table 3: Shows the specific regions of the cortex, the number of voxels assigned to the region by LORETA, the X, Y, Z Talairach Coordinates and the region of the brain.

ROI	# of Voxels[3]	X, Y, Z Talairach coordinates	Brain Region
Anterior Cingulate Gyrus	7	(-3, 31, 22) (-3, 24, 29) (-10, 31, 29) (-3, 31, 29) (-4, 31, 29) (-3, 38, 29) (-3, 31, 26)	Brodmann area 32, anterior cingulate gyrus, limbic lobe
Left Dorsolateral Prefrontal Cortex	3	(-38, 31, 36) (-38, 31, 43) (-31, 31, 43)	Brodmann area 8, middle frontal gyrus, frontal lobe
Right Dorsolateral Prefrontal cortex	4	(39, 31, 36) (39, 24, 43) (32, 31, 43) (39, 31, 43)	Brodmann area 8, middle frontal gyrus, frontal lobe
Right Post-central gyrus	5	(46, -25, 43) (53, -25, 43) (60, -25, 43) (53, -18, 43) (53, -25, 50)	Brodmann area 3, post-central gyrus, parietal lobe
Left supramarginal gyrus	5	(-59, -53, 15) (-59, -60, 22) (-59, -53, 22) (-59, -46, 22) (-59, -53, 29)	Brodmann area 40, supramarginal gyrus, temporal lobe
Right supramarginal gyrus	6	(60, -53, 15) (60, -60, 22) (53, -53, 22) (60, -53, 22) (60, -46, 22) (60, -53, 29)	Brodmann area 40, supramarginal gyrus, temporal lobe
Cuneus	7	(-3, -67, 22) (-3, -74, 29) (-10, -67, 29) (-3, -67, 29) (4, -67, 29) (-3, -60, 29) (-3, -67, 36)	Brodmann area 7, Cuneus, occipital lobe

Table 4: ANOVA table and the Type III test of fixed effects from the mixed models analysis.

ROI Session Round	Num *df*	Den *df*	F Value	*p*
ACcd	7	25	4.82*	.0015
LPFC	1	1202	250.48**	<.0001
RPFC	1	1214	144.96**	<.0001
RPCG	1	1219	9.41**	0.0022
RSMG	1	1221	5.23*	0.0224
LSMG	1	1212	0.10	0.7556
CUN	1	1195	0.04	0.8502
Rounds	5	44.4	1.42	0.2371
Session	32	198	0.78	0.7943
Ses*rnds	160	995	1.10	0.2125

$p \leq .05$* $p \leq .01$**

Table 5: Pearson correlation matrix of the seven ROIs in the trained (14-18Hz) frequency.

ROI	ACcd	LPFC	RPFC	RPCG	RSMG	LSMG
LPFC	.732*	-	-	-	-	-
RPFC	.625*	.783*	-	-	-	-
RPCG	.454*	.614*	.749*	-	-	-
RSMG	.101	-.024	.101	.120	-	-
LSMG	-.038	.014	.078	-.023	.257	-
Cuneus	.127	-.019	-.092	.033	.471*	-.638*

$p < 0.01$

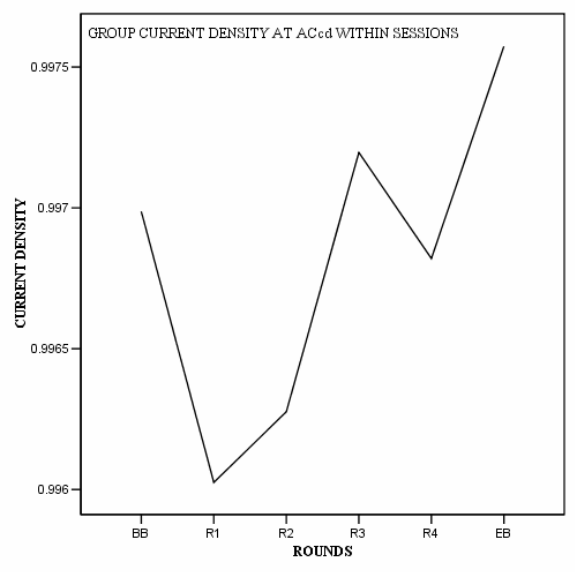

Figure 1A: Group means for current density averaged across sessions for each round and mean current density for pre (BB: beginning baseline) and post (EB: ending baseline) baseline measurements.

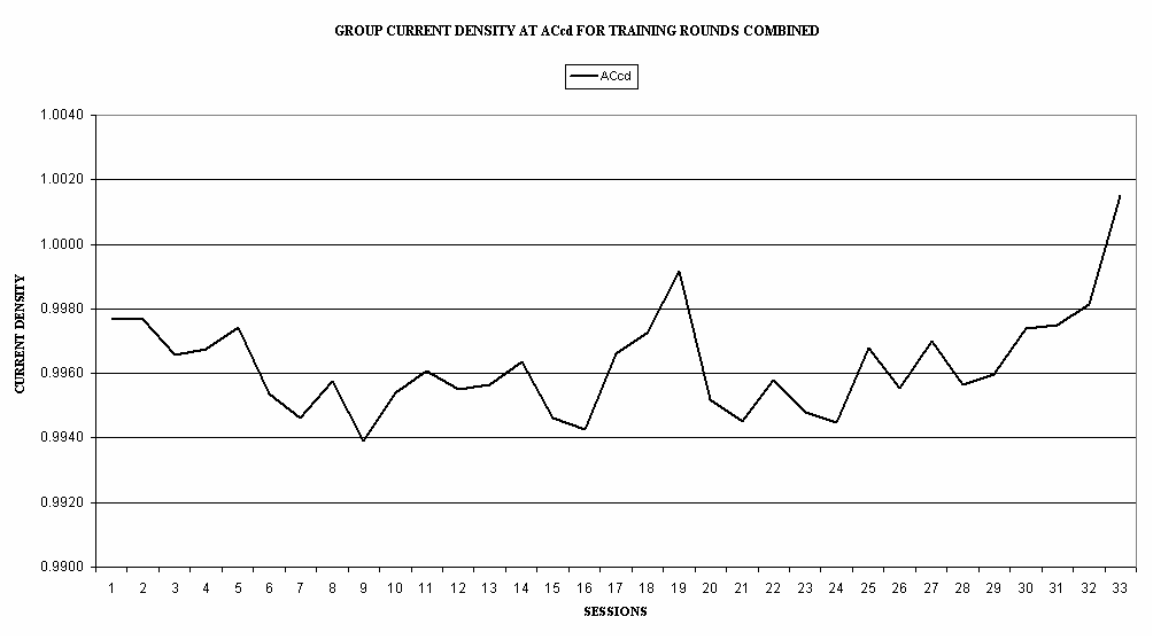

Figure 1B: Group average current density in the ACcd for the combined rounds of training over sessions. The trend is positive and significant (see table 4).

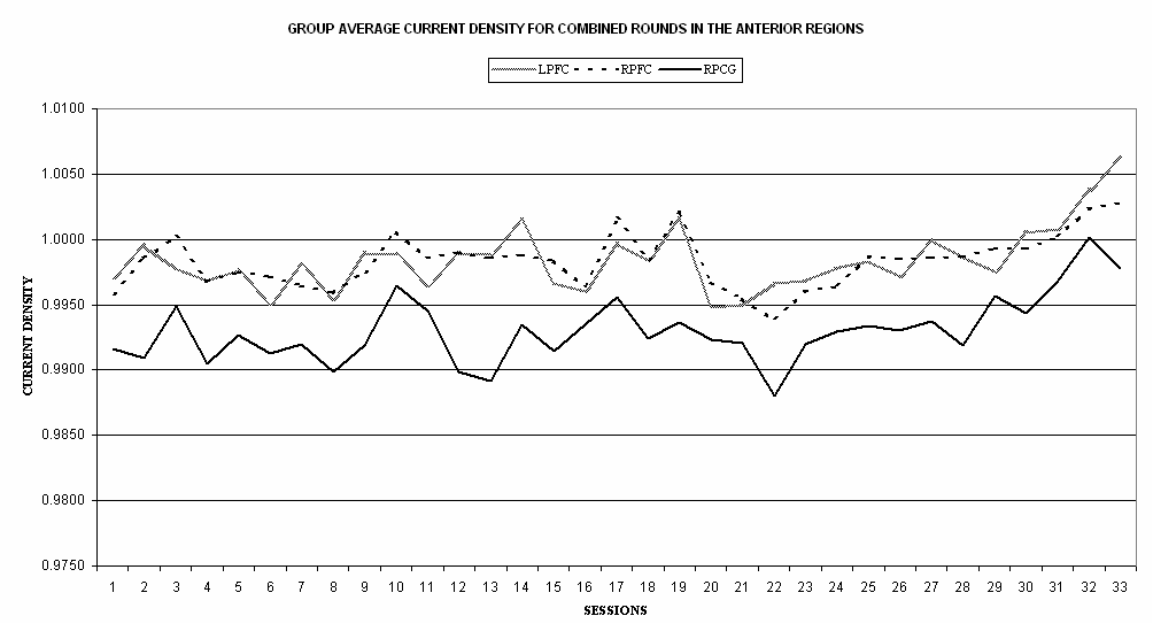

Figure 1C: Group average current density in the anterior regions of the cortex for the combined rounds over sessions. These regions increased at significant levels (see table 4).

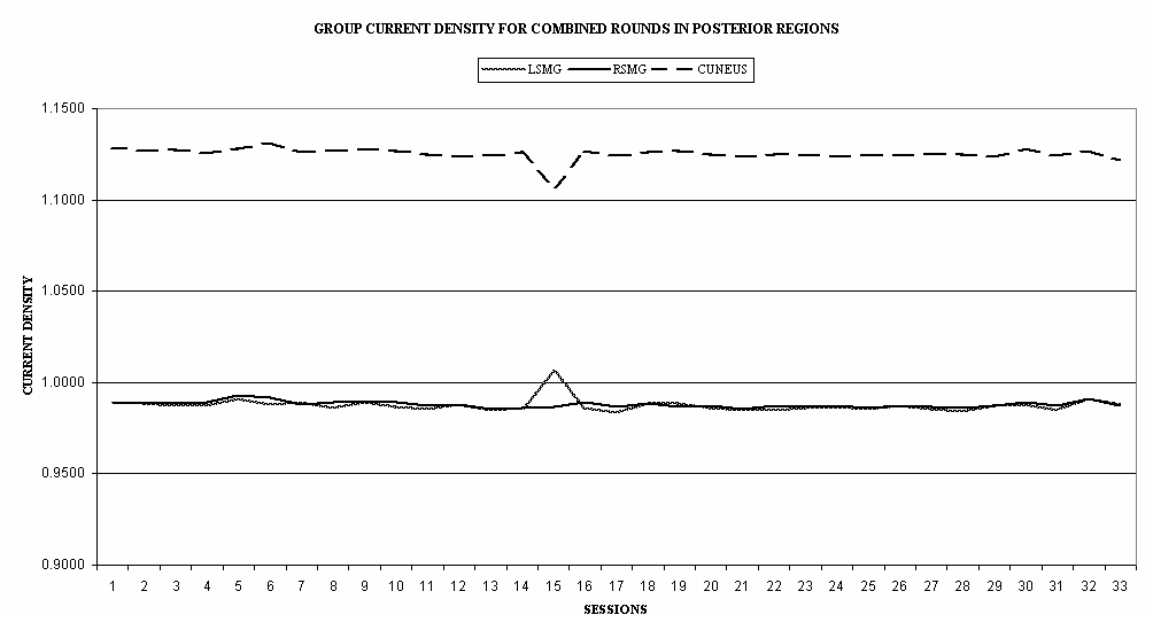

Figure 1D: Group average current density in the posterior regions of the cortex for the combined rounds over sessions. The activity in these regions decrease over sessions in the trained frequency (see table 4).

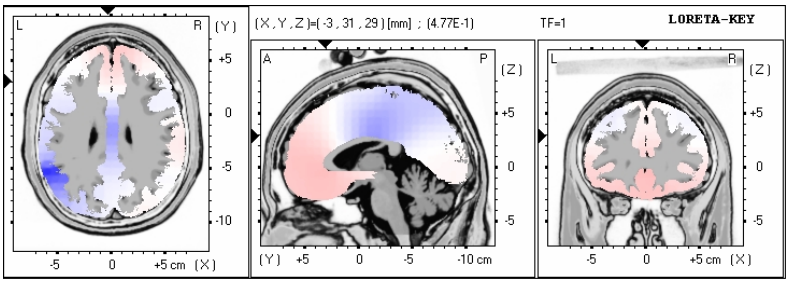

Figure 2A: This is a *t*-statistical image for the difference between pre and post eyes closed baseline comparison. This is a horizontal, sagittal and coronal view of the region of interest from left to right. The red in the image indicates regions of significant increase in activation, while the blue indicates significant decreases. The maximum increase given is at (X= 53, Y= 3, Z= -41) Brodmann area 21, Middle Temporal Gyrus, Temporal Lobe. In addition, as much of the data presents, the ACcd and ventral portions of the AC are also of significance. The maximum decrease is at (X= -59, Y= -53, Z= 22) Brodmann area 40, Supramarginal Gyrus, Temporal Lobe.

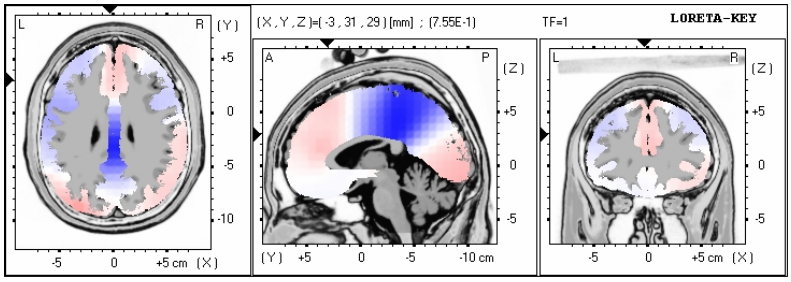

Figure 2B: This is a *t*-statistical image for the differences between pre and post eyes-opened baseline comparisons. This is a horizontal, sagittal and coronal view of the region of interest from left to right. The red in the image indicates regions of significant increase in activation, while the blue indicates significant decrease. The voxel of maximum increase in activation is at (X= 67, Y= -32, Z= -13) Brodmann area 21, Middle Temporal Gyrus, Temporal Lobe. The ACcd and right post central gyrus are of significant increase. The maximum decrease is at (X= -24, Y= -53, Z= 64) Brodmann area 7, Superior Parietal Lobule, Parietal Lobe.

Table 6: This table shows the results for the pre and post psychometric measures. There was no change in arithmetic and an insignificant change in LN sequencing. The differences in the other scores are of significance.

Group Pre - Post WAIS III Subtest and Index Scores

Subtest *Index	Mean	SD	95% Upper-Lower	Diff	*df*	F	*p*
Pre C	11	2.77	(8.67 – 13.32)				
Post C	13	3.20	(10.31-15.68)	+2	1,6	51.32**	0.0004
Pre A	13	3.02	(11.09-16.05)				
Post A	13	1.99	(11.95-15.29)	0	1,6	2.83	0.1438
Pre DS	12	2.99	(10.36-15.38)				
Post DS	15	4.36	(11.59-18.90)	+3	1,6	11.48*	0.0147
Pre SS	11	1.84	(9.83-12.91)				
Post SS	13	2.66	(11.14-15.60)	+2	1,6	14.01**	0.0096
Pre LN	12	3.70	(9.53-15.71)				
Post LN	14	2.54	(12.61-16.88)	+2	1,6	4.89	0.0691
*Pre WMI	117	16.44	(103-131)				
*Post WMI	128	17.64	(114-143)	+11	1,6	45.12**	0.0005
*Pre PSI	106	11.13	(97-115)				
*Post PSI	117	14.17	(105-129)	+11	1,6	23.93**	0.0027

$p \leq .05$* $p \leq .01$**

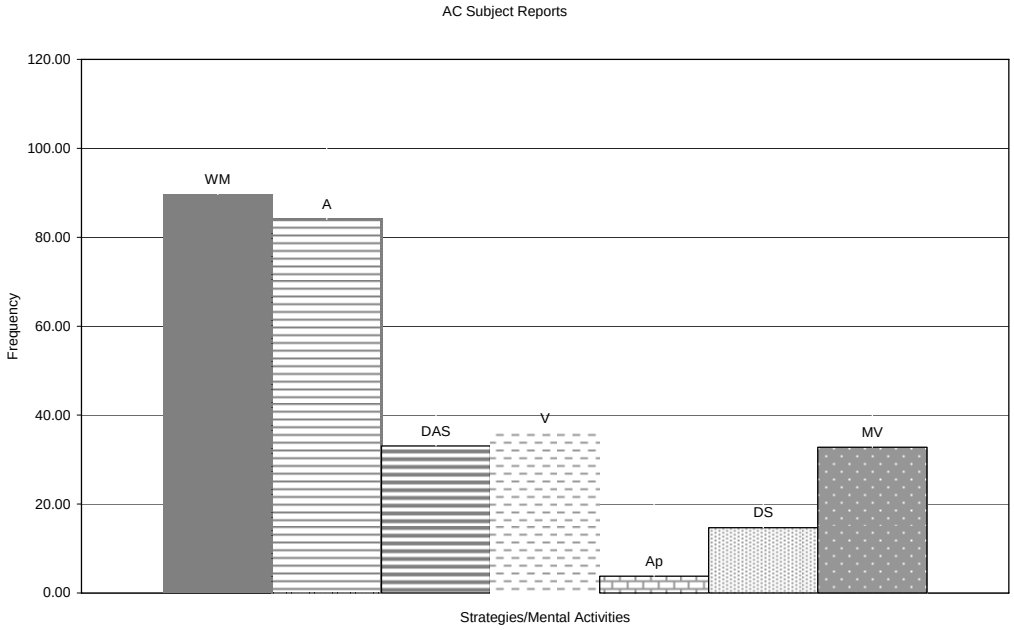

Figure 2C: Shows the frequency of the reported strategies and mental activities the subjects engaged in during the training rounds over sessions. The reports are WM = working memory; A = attention; DAS = Daily stresses; V = visualization; Ap = appetitive thoughts; DS = dissatisfaction; MV = mental verbalization.

Appendix II

Subject Information

All information is confidential and will not be released to any person for any reason. Please answer as honestly as possible.

Initials: _____ File Name:_____
Age: _____
DOB: _____

Sex: (circle one) Male Female

Handedness: (circle one) Right Left Ambidextrous

Date/Time_____

Questionnaire

1. Have you ever had an injury to your head? _____
2. Have you ever been unconscious? _____
3. Have you ever been diagnosed with any mental disorder (this includes Depression, Anxiety, Schizophrenic, etc.)? _____
4. Do you currently or have you ever taken any psychotropic drugs? _____
5. Do you currently take any medications? _____
6. If so what medication and for what? _____
7. Have you in the past two weeks used any non-prescription drugs (marijuana, etc.)? _____
8. Do you have a history of alcoholism? _____
9. Have you ever been diagnosed with cerebrovascular disease? _____
10. Do you have a history of Migraines? _____
11. Have you ever been diagnosed with epilepsy? _____
12. Have you ever been diagnosed with a learning disorder and/or ADD/ADHD? _____
13. Have you ever been diagnosed with any type of sleep disorder? _____
14. ----------
15. Do you have one hour of spare time M/W/F either in the morning or in the afternoon? Please specify your

availability_____
_____

16. This study will investigate your ability to change your brain-wave patterns in desired directions with the aid of feedback provided by a computer. It is only you that can achieve changes. The computer will not interfere with your brain activity. Please use the space below to explain your motivation in participating to this study:

Appendix III

Informed Consent Form

Title of Project: ***Low-Resolution Electromagnetic Tomography Neurofeedback: LORETA Neurofeedback in anterior cingulate gyrus***

Principal Investigators: *Rex Cannon, BA; Joel Lubar, PhD*

Objective of Project: The purpose of this project is to investigate your ability to change your brains' electrical activity in specified directions within specified regions. The data collected will help us to determine if it is possible to modify electrical activity within deep cortical structures.

Project Summary: You will participate in 30 training sessions. The training will consist of enhancing particular brain activities in selected regions of your cortex. Your electroencephalography (EEG) will be recorded continuously during each session. A computer will extrapolate meaningful information from your EEG and will give you feedback about your performance. You will be asked to obtain as much positive feedback as possible. Positive feedback will indicate that your brain activity is changing in the specified direction. The equipment will not influence directly your EEG activity, but will only provide you information. You might find the experience challenging or even frustrating, but you are asked to try your best on each session. You will undergo standard psychometric testing before and after the training, so to allow us to assess cognitive performance improvements as a result of the training. Your EEG will be recorded during each session. Three-minute eyes-closed and eyes opened baseline EEG will be recorded first, followed by the training session. Three-minute baselines will be recorded at the beginning and end of each session. To record your EEG, an electrode cap with 19 sensors will be placed on your head. Electrode gel is applied to each sensor by a small tube inserted through the sensor. The gel forms a conductive pathway between the sensor and the scalp. There is no significant discomfort with this procedure either in the preparation or the wearing of the cap during the testing. An ear clip electrode will be placed on each earlobe after a light cleaning with Omniprep solution, which removes skin oil and allows for good sensor contact. All creams and gels used during this evaluation are hypo-allergenic, with no known risk of irritation. Since muscle movements produce electrical activity which can contaminate the EEG, you will be asked to sit still, with eyes closed, in a relaxed posture. You will be receiving extra course credit for participating in this study, not to exceed the amounts prescribed by the Psychology Department at the University of Tennessee.

Amount of Time Required: Each session requires approximately one hour to be completed. There will be 30 sessions, consisting of three sessions per week during regular University of Tennessee hours.

Confidentiality: Only persons listed as Principal Investigators will have access to material that identifies you personally as a participant in this study. The data gathered during this experiment will potentially be shared professionally, but your name will be coded to prevent identification. These records will be stored in a locked file cabinet in the Brain Research and Neuropsychology Laboratory, A305 Walters Life Sciences, for at least three years past the duration of the study.

If you have any questions about this study, please feel free to ask them. Any future questions may be addressed to

Rex Cannon, B.A
Department of Psychology
Austin Peay, Suite 312
University of Tennessee, Knoxville 37996
865-974-3222
rcannon2@utk.edu

or

Dr. Joel Lubar
Department of Psychology
Austin Peay, Suite 312
University of Tennessee, Knoxville 37996
865-974-3222
jlubar@utk.edu

Direct problems or concerns to:

Compliances Section
Office of Research
1534 White Avenue
Knoxville, TN 37996-0145
865-974-3666

Statement of Consent:: I certify that I have read and fully understand the procedures contained within this form and agree to participate as a subject in the research described therein. My participation is given voluntarily and without coercion or undue influence. I

understand that I may discontinue participation at any time. However, I understand that students participating for extra credit will only receive credit and monetary compensation after completion of participation in the study.

_____	_____	_____
Signature of Participant	Name of Participant	Date

_____	_____	_____
Signature of Witness	Name of Witness	Date

Appendix IV:

Form B

IRB# _____

Date received in ORC_____

THE UNIVERSITY OF TENNESSEE, KNOXVILLE

I. Identification of Project:

Date: December 12, 2004

Project Director:	Rex Cannon, B.A. Department of Psychology Suite 312 Austin Peay Knoxville, TN 37996 865-974-3222 rcannon2@utk.edu
Faculty Advisor:	Joel F Lubar, PhD Department of Psychology Suite 312 Austin Peay Knoxville, TN 37996 974-3222 jlubar@utk.edu

Title of Project: *Low-Resolution Electromagnetic Tomography Neurofeedback: LORETA neurofeedback in anterior cingulate gyrus.*

Department:	Psychology
Starting Date:	January, 2005
Completion Date:	May, 2005

External Funding Agency: n.a.
Grant Submission Deadline: n.a.

II. Objective of Project:

The purpose of this study is to investigate the efficacy of Neurofeedback training of current density in the cerebral volume. Neurofeedback is an operant conditioning process by which the subject learns how to change his/her brain activity. The learning unfolds over several training sessions, usually 20 to 40. With the aid of real-time feedback provided by a computer the subject is able to continuously monitor his/her brain activity in selected regions and can learn to change it in wanted directions. Typically a rewarding condition is set at the beginning of the session. For example, the computer may be programmed to provide feedback any time the EEG power in the 10-13 Hz frequency band increases above 50 microvolts squared ($u\text{V}^2$). The computer then continuously extrapolates this measure from the EEG signal and provides visual and/or auditory rewards to the subject when the feedback conditions are met. The standard Neurofeedback is based on scalp potential electrical activity (Electroencephalography: EEG) and has been used regularly in this laboratory in the past 20 years. Low-Resolution Electromagnetic Tomography (LORETA) is a mathematical technique to derive intra-cerebral 3-D current density estimation from the scalp potential. It has been used worldwide in brain research since 1993. While scalp-recorded EEG consists of the superposition of the electrical activity of neurons located in brain tissue beneath the electrode, current density estimation refers to neurons electrical activity in specific brain anatomical areas. This allows the Neurofeedback process to be based on 3-D current source density instead of scalp potential and enables precise and specific training.

Clinical implications of the technique are potentially important, including the training of epileptic foci, language-related areas in the context of learning disabilities, attention deficit disorder, and in general any specific neo-cortical tissue. While previous studies showed the effectiveness of neurofeedback in the treatment of several neurological/psychiatric disorders, to our knowledge, no study to date has investigated 3-D current density neurofeedback or the possibility of training the anterior cingulate cortex.

III. Description of Subjects:

Subjects will be recruited from the Psychology Department Subject Pool. For specifics of the recruitment method please see Section V.

IV. Methods or Procedures:

We plan to execute a series of single-subject studies and to recruit a maximum of 8 subjects. Each subject will initially be screened for neurological and/or psychiatric

status by means of a standard questionnaire previously used in other studies by this laboratory. Only those subjects who do not report any neurological/psychiatric disorders and who are not taking any psychoactive medication during the time of the study will be selected. On the basis of this selection, potentially suitable subjects will be asked to participate in the experiment. These subjects will be further interviewed in order to ascertain their motivation in participating in the study.

Subjects potentially included in the training sessions will receive extra course credit for participation in this study. Those subjects who accept the offer will be initially presented with an informed consent form, which must be signed before the experiment begins. They will also undertake a preliminary EEG evaluation, which will be performed by standard data analysis procedures employed in this laboratory. The subject's EEG features will be compared with a normative database in order to assess his/her deviance from normative EEG values. This information may be used for establishing the neurofeedback protocol. The training will consist of 30 1-hour sessions. Sessions will start after the first day of classes and will be completed by the last day of classes within each semester. The sessions will take place in a sound-attenuated room of our laboratory. During each session the EEG will be acquired continuously following the International 10-20 system for electrode placement. Hookups will be made using an electrode cap (Electro Cap Inc.) and Electrogel conductive cream (Weaver and Co.). Subjects will have the electrode cap with 19 sensors placed on their heads. Electrode gel is applied to each sensor by a small tube inserted through the sensor; the gel forms a conductive pathway between the sensor and the scalp. There is no significant discomfort with this procedure either in the preparation or the wearing of the cap during the testing. Two ear clip electrodes will be placed on the earlobe after a light cleaning with Omniprep solution, which removes skin oil and allows for good sensor contact. EEG data will be collected during the experimental procedure by means of a Deymed Truscan fiber-optic digital EEG data acquisition device.

Once this cap has been put in place, the electrode impedance will be tested with impedance values provided by the Deymed and adjusted $\leq$ 5 Kohms. At this stage 3-minute eyes-closed and eyes-opened pre-baseline will be recorded. A minute later the training session will start. The subject will be seated in a comfortable chair in front of a computer screen and will be instructed to try to obtain as much feedback as possible. Feedback signals may consist of tones emitted from the computer in a 3-D game on the computer screen. Each of the training sessions will be approximately 20 minutes in length, consisting of four, four-minute rounds. Finally, a 3-minutes eyes-closed and eyes-opened post-baseline will be recorded. At the end of the second baseline the EEG recordings will end. The cap will be removed, and the electrode gel, which is very similar to hair mousse, will be wiped off with a tissue or paper towel. All creams and gels used during this evaluation are hypo-allergenic, with no known risk of irritation. The entire procedure for each session should be completed in one hour. Our laboratories have used this method of application in previously approved projects since 1985. Training protocols employed in this research will be fixed upon completion of initial training round for all participants. On the basis of the preliminary EEG evaluation (see above) the protocol may involve the normalization of extreme EEG features (as compared with the normative

database) of the subject. Fixed protocols that will be used are the low-beta (14 – 18 Hz) power enhancement in the cognitive division of anterior cingulate. A large body of literature suggests that frontal midline theta (generated in the anterior cingulate) is involved in working memory cognitive tasks. Enhancing low-beta power in this region should improve working memory and processing speed skills. Standardized psychometric evaluations will be performed on each subject before and after the training. The goal is to assess changes in cognitive performance. Tests employed will be the WAIS-III (Wechsler Intelligent test for adults, selected subtests for working memory and processing speed with be used for pre-post comparison). Psychometric tests will be administered by or under the supervision of Teresa Hutchens, counseling psychologist with over 20 years of experience in neuropsychological testing.

V. Specific Risk and Protection Measures:

EEG data acquisition and LORETA neurofeedback training sessions will be performed in the Brain Research and Neuropsychology Laboratory, namely by Rex Cannon. Scalp EEG neurofeedback presents minimal risk to human subjects. It has been used in this laboratory over the past 20 years and no case of harmful effects has been reported. LORETA neurofeedback is in principle equivalent to scalp EEG neurofeedback, with the exception of its spatial properties cited above (II). To our knowledge, no previous research has been using this paradigm.

Recruitment: Subjects will be recruited via the Psychology Department Human Subject Pool, and will receive extra credit according to the agreement between the Psychology Department and the Human Subjects Research Committee. Sign-up sheets will be posted in the designated area of Austin Peay Building, and professors will be asked to make announcements.

Procedures to Maintain Confidentiality: Names, telephone numbers, and scores of all subjects will be recorded in our files. These records will be stored in a locked file cabinet in Room 305D of Walter Life Science Building. Access will be restricted to Dr. Lubar and Rex Cannon. Data entry (into the computer data file) will not include names or other identifying information. Immediately following data input, the hard copies of names and other identifying information will be destroyed via shredding. Confidentiality will be maintained with respect to the EEG data because only subject ID numbers will be used.

VI. Benefits vs. Risks:

Benefits to the students for doing this study include monetary compensation and extra-credit for participation. An additional benefit will be the advancement of knowledge in the field of EEG research. The risk to either physical or psychological well being of any subject participating in this study is minimal. At the beginning of each session subjects will be told that they can withdraw from the study if they feel uncomfortable at any time without penalty.

VII. Methods of obtaining "Informed Consent" from subjects:

Subjects who meet the criteria and who are suitable for inclusion in the experimental groups will be offered monetary compensation (see IV) to participate in the training. Those subjects who accept the offer will be initially presented with a consent form, which must be signed before the experiment begins. All subjects will be required to read and sign the informed consent form (see attached Consent Form) prior to participating in each of the parts of this study.

VIII. Qualifications of the Investigators:

Rex Cannon is a graduate student in the experimental psychology program at the University of Tennessee. He has been involved in the brain research laboratory for four years and coordinator for the brain research laboratory for the three years.

Dr. Joel Lubar is a Full Professor in the Department of Psychology at the University of Tennessee, and has over 35 years of experience working in the field of neuroscience. He is a licensed Psychologist within the State of Tennessee, with the designation of "Health Service Provider."

IX. Adequacy of Facilities to Support Research:

The physical requirements for carrying-out the training sessions in this study are completely adequate. The Psychology Department at the University of Tennessee has the requisite space and computer equipment for implementation.

Data collection and training sessions for this study will be accomplished within the Brain Research and Neuropsychology Laboratory in Walter's Life Sciences Building, University of Tennessee. Equipment to be used is owned by either Dr. Joel Lubar, or the

University of Tennessee. All instrumentation and test materials to be used in this study are directly comparable to materials used in hospitals and clinical settings.

X. Responsibility of Project Director:

By the Compliance with the policies established by The University of Tennessee, Knoxville, Committee on Research Participation, the project director subscribes to the principles stated in "The Belmont Report" and standards of professional ethics in all research, development, and related activities involving human subjects under the auspices of The University of Tennessee, Knoxville.

a. Approval will be obtained from the University Committee prior to instituting any change in the research project.
b. Development of any unexpected risks will be reported to the University Committee.
c. A status report (Form D) will be submitted at 12-month intervals or as requested attesting to the current status of the project.
d. Signed consent statements will be kept for the duration of the project and for at least three years thereafter.

Project Director: _____
Rex Cannon

Date: _____

Faculty Advisor: _____
Dr Joel Lubar

Date: _____

XI. Departmental Review and Approval:

The application described above has been reviewed by the IRB departmental review committee and has been approved. The DRC further recommends that this application be reviewed as:

[] Expedited Review—Category(ies):_____

OR

[] Full IRB Review

Department Head: _____ Date:_____
Dr. James Lawler

Chair, DRC: _____ Date:_____
Dr. Kathleen Lawler

Protocol sent to Compliances Section for final approval on_____

Approved: Compliances Section
Office of Research
404 Andy Holt Tower

VITA

Rex Cannon was born in Portsmouth, Virginia. He was raised and lived in the Norfolk, Virginia beach area. He attended elementary and high school in both Virginia and in Blount County, Tennessee. He received his Bachelor's Degree from The University of Tennessee in 2004 and is currently working toward a Master's Degree in experimental psychology with an emphasis in neuroscience and a minor in statistics.