

## **Intentional Control of Regional Cerebral Blood Flow with the Thinking Cap.**

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**Introduction to Voluntary Cerebral Blood Flow:** Increased blood flow to active brain areas is demonstrated in many PET, fMRI, and SPECT studies. Many such studies have shown abnormal regional cerebral blood flow (rCBF) in brain disorders such as Schizophrenia, Alzheimer's, Parkinson's, Attention Deficit Disorder, substance abuse, depression, dementia and others. Blood supplies oxygen and glucose to support energy requirements of brain metabolism. The Delta and Theta activity in the EEG has also been shown to correlate highly to regional cerebral blood flow (rCBF) (2,3,11,16). Studies of brain activities using these scanning instruments show increased blood flow and metabolism in brain areas activated by the experimental subject during selected brain functions. The subject has no awareness of the brain locale activated. The choice of active brain locales is entirely unconscious. Increased vascularity developed in enhanced environments has been demonstrated in rodents (M. Rosensweig, and Diamond 1962) but has not been shown in humans.

**Purpose:** This study examines intentional increase of blood perfusion in a chosen brain area when the subject is suitably informed of the rCBF of that brain region. The study evaluates increased vascularity at the chosen sites due to exercise.

**Method:** The interior of the skull is not dark.. Incident light on the head penetrates the translucent scalp and skull. This fact has been amply demonstrated many studies since 1980. A spectrophotometer depending on the translucent characteristics of the scalp and skull was used to examine the oxygenation of capillary beds in cerebral cortex (6,7,8,9,10,13). Dual light sources, red and infrared, in contact with the scalp provided cortical illumination.. The instrument readings are minimally affected by many inter subject variations such as intervening sinus volumes or cerebral spinal fluid filled spaces. A ratio computation reduces the effect of variation of incident light intensity and light absorption by the intervening tissue volume. This ratio approximates the ratio of oxygenated to deoxygenated cortical blood. Arteries form a small proportion of the tissue volume illuminated compared to the capillaries. The micro circulation, is the most likely source measured. Pre-Tests: Voluntary control of blood flow at the illuminated position was discovered while the instrument was under development. An initial experiment to determine the effect of intentional increase of oxygenation was undertaken with 40 volunteers. Most subjects found intense concentration on the task increased the reading of the instrument placed over the left prefrontal cortex at Fp1. Concentration greatly facilitated a rise in indicated oxygenation.. It was generally observed that learning to manipulate the indication at Fp1 required less than 3 minutes with suitable coaching. It was often reported that this form of brain exercise was intense, tiring, and self limiting. It could be tolerated for a only a limited time before rest was required. Most subjects reported a somewhat awakened state after a 10 minute exercise period. Further experimentation illustrated the completely unconscious character of the movement of blood to the feedback site. Figure 1 shows an experiment using blood flow instruments at different brain sites Cz, and Fp1. Audio feedback was shifted from Cz to Fpz. Blood flow followed the site from which feedback arose. The subject was unaware of the feedback source.

**Subjects:** A group of 4 subjects presenting with various mental difficulties was selected for intensive training. Two were severely depressed, another was reported by T.O.V.A. to be ADD and the 4th with a working memory defect was unable to read comfortably. Figure 2 shows growth in perfusion for the 4 subjects resulting from brain exercise.

**Results:** The graph reflects blood perfusion at the beginning of each session. The changes occurred in the inter-session interval when the subjects were engaged in ordinary daily activities. This suggests a growth effect due to the exercise of the preceding session. The correlation coefficient, 0.902 for the 4 subjects' data shown by Figure 2, demonstrates that rCBF can be intentionally controlled by a subject when given suitable current

information. The Pearson rho correlation coefficient ( $r=.902$ ,  $p< .05$ ), illustrates the significant goodness of fit of the straight line to the experimental data. This strongly suggests growth of the micro circulation between sessions and may account for a major part of mental improvements gained with all types of neurofeedback.

**Discussion:** The ratio of within session maximum to minimum blood flow, calculated for each session shows little gain after the first 2 or 3 sessions. Most of the required learning is easy and occurs in the first session with smaller improvements in later sessions. The data support the growth findings of Rosensweig and Diamond, experience modifies the physiology of the brain, and is now shown to be likely in human brains. Effect of Scalp Blood Flow: The right and left anterior temporal arteries supply the major portion of forehead skin and muscles (Grays Anatomy p 495). Variation of the oxygen content of these arteries and the tissues they supply has a negligible effect on instrument readings. With the instrument mounted at Fp1, occlusion of the anterior temporal arteries at the level of the auditory meatus, which supplies blood to the forehead area, reduces readings by less than 5%. Perfusion of the scalp is thus shown to have a very small effect on the readings. Now that one can direct blood to deficient cortical areas a new dimension to brain therapies has been added. One can speculate that there is therapeutic value in directed voluntary control of rCBF to specific brain sites. This remains to be validated and is being actively pursued. Some therapeutic results have accumulated to date: These are elucidated in follow on reports.

**Key Words:** hemoencephalography, infrared, brain blood flow, spectrophotometry.