# Intellectual, Auditory and Photic Stimulation And Changes in Functioning In Children and Adults

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Reliably improving brain functioning through the systematic influencing of the brain's direct experience now appears closer to becoming a reality. This possibility, the current research findings that suggest it, and some of the implications of the research are the primary focal points of this article.

The concept itself is not new, dating back at least 2,000 years. What is new is the technology, such as EEG brain mapping and the use of neuroradiological hardware and software such as SPECT, PET, MRI and functional MRI, which permit accurate observation and measurement of the brain's response to either a single stimulus or repeated stimuli. Work done at the University of Washington over the past several years has documented the brain's neurocirculatory response to intellectual challenge (the stimulation of learning to perform a difficult task) as well as the neurocirculatory response to photic stimulation.

Every part of the neuron from soma to synapse changes in response to the stimulation it receives (Diamond, 1988). There is substantial evidence that experience directly affects neuronal pathways even though the mechanisms aren't yet

clear (Steward, 1993, cited by Larkin, 1993). "Me brain is always growing and changing. The inherent plasticity must contribute to recovery after damage as well as to learning and memory (Kaplan, 1993, cited by Larkin, 1993). Neuronal plasticity, the brain's adaptation and reorganization as a response to its direct experience of various forms of stimulation, is a widely recognized concept of increasing interest to many brain researchers and clinicians involved in treatment of brain dysfimction.

Systematic changes in the levels of activity of neurons or networks of neurons have been observed to occur following Stimulation Induced Neural Activation (SINA), an umbrella term that covers diverse forms of stimulation. While many forms of stimulation have been reliably reported to produce brain functioning changes (e.g., Illis, 1983), coverage of all of the stimulation literature is beyond the scope of this article.

I will describe two kinds of stimulation that, although different in their form, appear to produce similar responses in the brain. The first is the stimulation and neuronal activation produced by the intellectual challenge of learning a new and difficult task. Ile second is the neuronal activation resulting from photic and auditory stimulation. Both forms of stimulation, when used repetitively, appear to bring about changes in brain functioning that can be measured not only by changes in EEG frequency activity, increases in glucose and oxygen metabolism, increase in regional cerebral blood flow, changes in brain chemistry, etc. (e.g., Walter and Walter, 1949; Sappey-Marinier, et al., 1992; Posner and Raichle, 1994), but also by changes in behavior.

**Intellectual Stimulation**

I strongly believe, based on my own experience and the reports of many others, that learning to regulate EEC; frequency activity through biofeedback training (EEGBF) qualifies as learning a complex task-for me, it was very difficult, frustrating and time consuming. Teaching this hard won skill to others could be described in the same terms: difficult, frustrating and time consuming. Seeing the cognitive and behavioral improvements in others after their successful acquisition of the EEGBF control skills (Carter and Russell, 198 1) did offer some personal and professional satisfactions to offset many of the frustrations.

Much of the EEGBF literature can be thought of as evidence that learning a complex and difficult task alters brain functioning (and probably brain structure) immediately and long term. There is even current evidence of a relationship between an increased number of years of education and greater dendritic length (a measure of brain development).

"Me EEG literature is extensive (Byers, 1996). The results of currently reported controlled studies strongly suggest that marked increases in cognitive abilities occur in children following EEGBF (see, e.g., Linden 1996; and Cartozzo, et al., 1995). In well documented reports extending back over many years (Lubar, 1995; Tansey, 1993), the results indicate that EEGBF training is followed by significant increases in cognition and improvements in behavior. The gains, once made, appear to be maintained over time (a point that will be discussed later in relation to the results of the photic and auditory stimulation studies).

Unfortunately, EEGBF training requires expensive equipment, highly experienced technicians and is usually done on a one to one basis. The cost factors of this form of stimulation appear to restrict its use to probably no more than five percent of the people, children or adults, who would benefit from it. An alternative that could produce similar gains at a much lower cost would have significant implications for both research and treatment.

## Auditory and Visual or Photic Stimulation (AVS)

The possibility that auditory and visual stimulation (AVS) might be a possible alternative to EEGBF in improving brain functioning was raised by a serendipitous event about 10 years ago. A friend had experienced a right middle cerebral artery aneurysm and surgical removal of the resulting hematoma. She was left with severe cognitive and motor impairments including left sided paralysis.

Several sessions of EEGBF resulted in gradual and fairly rapidly increasing cognitive gains, which I had hoped would occur. What I had not expected to see was smoothly flowing involuntary movement occurring in her paralyzed left arm and leg after 15 to 20 minutes of EEGBF training. In the opinion of the consulting neurologist overseeing her training, the movement was not the kind of jerking movement associated with seizure activity. Serendipity took the form of a photic stimulating device with an adjustable flicker rate and an adjustable light intensity level (loaned to me by a friend and fellow psychologist). Use of this device resulted in the same kind of smoothly flowing involuntary movement within 15 to 30 seconds that was produced by the use of EEGBF after 15 to 20 minutes. In both procedures, the smooth, flowing movement was folowed by decreases in spasticity lasting from 2 to 3 hours up to 2 to 3 days.

The work with my friend has continued at irregular intervals over the past 10 years. Cognitively, she has regained between 50 and 70 IQ points (enabling her, among other things, to pass her BCIA certification tests about five years ago).

She has worked for the past couple of years as a medico-legal consultant to a law firm and has just accepted a college level teaching job in her field of nursing. In her opinion, "the gains I made have never decreased. The gains were greater when I was working hardest (on the stimulation) and plateaued when I wasn't working but I kept whatever gains I made." Physically, she has made and continues to make significant gains in mobility, in gross and fine motor control and in her proprioceptive and sensory abilities.

I have worked with other stroke patients (including my wife) with similar long-lasting improvements. In addition to these case studies, there are large scale controlled studies which are much more likely to be regarded as reliable evidence about the positive effects of challenge and stimulation on brain functioning. Accordingly, the results of several such studies are presented.

Change may be a function of learning a difficult task, whether that of EEGBF or of EMGBF (electomyographic biofeedback). There was significant (.0001) improvement in cognition and behavior between the experimental group of learning disabled boys who learned EMGBF versus the control group boys (attention placebo and no treatment). A three-year study of 801 children was funded by the U. S. Department of Education (Carter & Russell, 1984; Carter & Russell, 1985). At one-year follow-ups, the differences between the experimental and control group boys were maintained.

More recently, controlled EEGBF studies of school aged children have reported (Linden, 1996; Cartozzo, Jacobs & Gevirtz, 1995) documenting changes in functioning similar to those reported earlier by Lubar and Tansey. Collectively, the studies indicate improvements in functioning that appear to be related to their having experienced EEGBF training.

A pilot study was done using fixed frequency photic stimulation synchronized with binaural auditory stimulation, with learning disabled boys having significant discrepancies between measures of their Verbal and Performance IQ scores (Carter & Russell, 1993). Significant improvements in cognitive functioning were found as were improvements in behavior as rated by parents and teachers. The gains appeared to be the greatest in the areas of the child's lowest functioning (whether Verbal or Performance) suggesting the possibility that one effect of this kind of stimulation may be a normalization of hemispheric functioning discrepancies. In addition, the amount of improvement appeared to be related to the number of training sessions.

The pilot results appeared to warrant further exploration. We sought and received funding from the U. S. Department of Education (through the Small Business Innovative Research Program (SBIR)) for two major purposes. First, we wanted to determine if the use of AVS could be a non-pharmacological and cost effective method of treating LD/ ADD/ADHD children so that they could attend more efficiently in school and be less impulsive and hyperactive. Second, we wanted to determine if a combination of the EEG with AVS (simple enough to be used in schools by school personnel) might be a cost effective tool in the treatment of LD/ADD/ADHD children. Combining the EEG and AVS into a single device (EEG/AVS) appeared to be a way to let the brain regulate its own rate of stimulation through a process called entrainment in which the brain attempts to match its frequency activity to that of an external auditory or photic stimulus. The device could be set to flicker at the same rate as the dominant frequency of the

EEG. By offsetting the flicker rate from the dominant frequency by a small amount above or below it, a gentle leading upward or downward of the dominant frequency could be induced. The melding of the concepts into working hardware and software was patented (Carter, Ochs, & Russell, 1995) and other patents have been received or are pending. The theory behind the use of the variable frequency stimulation was that it might induce a wider range of frequencies of neural activation than would be induced by the fixed frequency stimulation. The comparative efficacies of the two procedures have not yet been determined. Both procedures appear to produce cognitive and behavioral changes in both children and adults.

A Phase I U. S. Department of Education SBIR award of S30,000 to establish feasibility was followed by a two year, *$190,000* Phase II award. Several separate studies were conducted with the data analysis phase being done as this report is being written.

A 16-month follow up was done with the boys in the Phase I study. The cognitive gains observed at the end of the training sessions (and some of the behavioral improvements) were maintained. Gains in dependent academic measures that were not significant at the end of training were significant on 16-month follow-ups suggesting that the effects of the training continue after training has ended.

Another group of boys studied during Year I of Phase II showed significant cognitive and behavioral gains that were maintained on nine-month follow-ups. One pattern that appears to be increasingly clear is that the amount of improvement is related to the number of training sessions.

The effects of the training on LD/ADD/ADHD girls was studied during Year 11 of Phase 11 at the University of North Texas with the selection, training and testing of subjects under the university's control to establish replicability. This study found that girls made cognitive gains similar to those of the boys we studied and the results are being prepared for publication.

Currently, data analysis is in process on the final phase of Phase 11. We were interested in comparing the effects of EEG/AVS training alone with those of stimulant drug (Ritalin) therapy alone. An additional comparison was made with children receiving both EEG/AVS training and stimulant medication therapy (Ritalin). Previous work (Lou, Henricksen, Bruhn, et al., *1989;* Zametkin, Nordahl, Gross, et al., 1990) has indicated that a reduced blood flow (hypoperfusion) in the corpus striatum is found in children and adults with ADHD problems and that one of Ritalin's mechanisms of action is to increase blood flow in that area. Other work (Fox & Raichle, *1985)* has shown that photic stimulation increases striatal blood flow with variations in perfusion related to the rate of stimulation. If the two forms of stimulation (chemical and photic) have a common mechanism of action, then the possibility arises of the combination having an additive or integrative effect. A possible outcome might be a reduction in the amount of medication required to have a therapeutic effect.

Additional information being analyzed at this time is that of EEG data collected during the EEG/AVS training sessions. When the analysis is complete, it could answer the important question of whether or not the stimulation results in changes from slower frequency activity to faster frequencies within sessions and across sessions. The only statement that can be made at this time is that partial results are intriguing

**Summary**

The use of either EEGBF or auditory and visual stimulation (whether fixed frequency or variable frequency as in the EEG/AVS) appears to result in quantifiable changes in the brain. The changes may be electrical as measured by the EEG or circulatory as measured by neuroradiological procedures (SPECT, PET or MRI). They appear to be equivalent measures of the same process, stimulation induced neural activation (SINA) (Fox & Raichle, *1985)*. They may result from either the active learning required by EEGBF or the passive participation characteristic of EEG/AVS. Repeated activation, as in EEGBF or the use of the AVS or EEG/AVS reported here, appears to bring about improvements in cognitive functioning and behavior that may continue to exist after the original stimulation has ended.

Clinical findings frequently precede the basic research needed to delineate why changes in functioning occur. There appears to be a reasonable possibility that SINA results in increased growth and development of the brain. Completion of our data analysis, replication of these findings by other investigators and basic research into the mechanism of action are all needed. There is other recent and ongoing work in both clinical and basic research areas regarding SINA and its effects on brain functioning. The investigations are being conducted by Drs. Budzynski and Kogan (University of Washington-Seattle), Chandler (University of North Texas, Denton), Lubar (University of Tennessee, Knoxville), Montgomery (Nova Southeastern University, Ft. Lauderdale) and Rosenfeld (Northwestern). Until more data is avail

able, the theories and data presented here should be regarded with an open-minded skepticism.

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