Changes in attention span, activity, and levels of 5-HIAA in hyperactive children receiving EMG feedback

by Paul Edwin Moes

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Psychology
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Abstract:
Four hyperactive children were given electromyographic ("muscle") biofeedback in a single case design study. All four of the children were able to reduce muscle tension levels as measured by the EMG machine. Two of the children were able to significantly increase attention span and two showed increases in levels of 5-hydroxyindole acetic acid (a metabolite of serotonin) in the urine. None of the subjects showed changes in overall activity levels as measured in this study. The findings suggest, then, that EMG feedback is an effective tool in improving one aspect of their behavior in at least some hyperactive children. Findings concerning biochemical correlates and its clinical implications are also discussed.

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Date July 25, 1979

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ABSTRACT

Four hyperactive children were given electromyographic ("muscle") biofeedback in a single case design study. All four of the children were able to reduce muscle tension levels as measured by the EMG machine. Two of the children were able to significantly increase attention span and two showed increases in levels of 5-hydroxyindole acetic acid (a metabolite of serotonin) in the urine. None of the subjects showed changes in overall activity levels as measured in this study. The findings suggest, then, that EMG feedback is an effective tool in improving one aspect of their behavior in at least some hyperactive children. Findings concerning biochemical correlates and its clinical implications are also discussed.

INTRODUCTION

Prevalance and diagnosis of hyperactivity. It has been estimated that the "hyperactive child syndrome" (Cantwell, 1975) is present in 4 percent of grade school age children (Millichap, 1968). In a study of the grade school population of a school system in Illinois, Werry and Quay (1971) identified 2.5 percent of the population as exhibiting the "symptoms" of hyperkinesis (i.e. always on the go). However, these estimates of prevalence are somewhat unsure since identification of this syndrome can vary a great deal depending on the criteria being used at the time. When discussing prevalence of minimally brain dysfunctioned children, which includes hyperactive children, Wender (1971) points out that "its prevalence is, among other variables, a function of one's demands for diagnostic precision" (p. 59).

Wender, as well as other writers, have discussed the possibility that hyperactivity is not the result of one single element, but rather may be an outward symptom that can result from various underlying causes. In reviewing the literature of the hyperkinetic syndrome it is seen that much of the research in this area has focused on finding some element or cause that is common to all hyperkinetic (or in the more broad outlook, minimally brain dysfunctioned) children. However, even in studies that have shown statistical differences between normal controls and groups of hyperkinetic children, there are almost always some in the experimental group that show normal or near normal values for the variables being studied. Also, in many studies that are unable to show differences between the control and treatment groups, it can often be explained as due to the fact that some individuals in the treatment groups responded negatively to the treatment producing a null effect. Therefore, to better understand this syndrome, it is important to understand the various behavioral and physiological aspects that correlate with a given subgroup or individual in the general category of hyperkinesis. As S. Ambrosino (1975) states concerning minimal brain dysfunction (MBD), "MBD is a heterogenous phenomenon cutting across the whole nosological spectrum" (p. 73).

For this reason, rather than demanding a diagnostic precision that includes a variety of symptoms, it was decided that it would be best to look at each subject individually and to see if some of those characteristics that are shown by hyperactive children can be reduced in that individual. The term hyperactivity, then, will refer to the clinical signs of hyperkinesis, restlessness, distractability, lack of self-control, short attention span, and a generally excessive, socially inappropriate, motor activity (Renshaw, 1974; Laufer & Denhoff, 1957). The behavioral aspects of attention span, motor activity, and self control will be concentrated on most heavily.

Non-behavioral components of hyperactivity. Several non-behavioral aspects of hyperactivity have also been studied. Two examples of these are EEG factors and levels of various neurotransmitters. Both have been thought to reveal either a basic cause or an indirect correlate that results from a more basic problem (Brase & Loh, 1975; Satterfield, et al., 1973; Satterfield & Cantwell, 1974; Wender, 1971). For example, decreased power in the alpha range of a group of hyperactive children was thought by Shetty (1971) to reveal a "disorder of inhibitory mechanisms in the central nervous system" (p. 476). In another example, Brace & Loh (1975), and Bhagavan, et al. (1975) show evidence in support of the idea that decreased levels of 5-hydroxytryptamine (also called serotonin) is a possible cause of minimal brain dysfunction (including hyperkinesis). However, it should be remembered that while these components have been shown to be correlated, this does not necessarily reveal a cause and effect relationship. Also, even if studies show a statistical difference for a given variable, there still could be a great deal of variation within the experimental group.

5-Hydroxyindole acetic acid (5-HIAA), a metabolite of serotonin, vanillylmandelic acid (VMA), and other urinary monoamine metabolites of various neurotransmitters in children with MBD were examined by Wender, et al. (1975). They were unable to reveal any differences between MBD children and controls as to the levels of the metabolites. They also showed that treatment with effective doses of d-amphetamine increased levels of epinephrin and metanephrine in the urine. None of the others showed an increase. However, as stated previously, research involving a group of children can often mask the individual variation among the children. For example, some who may have been more hyperactive, may also have had lower levels. Another problem with this research is that only a small sample was used for comparison. Therefore, even though values obtained were suggestive of the hypothesis (that hyperactive children have lower values for the neurotransmitters), the N's for the groups were too small to obtain a significant difference.

It is generally assumed, then, by most workers that amphetamines, which was used effectively in hyperactive children, work by causing changes in levels of certain neurotransmitters (Satterfield, 1971). Three other studies suggest that levels of serotonin (and 5-HIAA) may be related to variables other than the administration of amphetamines. Bhagavan, et al. (1975) found that oral administration of phridoxine hydrochloride (Vitamin B_6) resulted in an appreciable increase in the serotonin content of hyperactive children who had shown significantly lower levels of blood serotonin as compared to controls. However, this study did not include any analysis of behavioral changes that might have occured. Greenberg and Coleman (1975 and 1976) have shown that an effective drug response may be predicted by the level of whole blood serotonin present before administration of the drug. A study by Coleman (1971) suggests that serotonin levels may be correlated with social or behavioral conditions. When two extremely hyperactive children, whose serotonin levels were well below the norm, were cared for at a clinical research center, their serotonin levels increased dramatically as well as their attention span and general clinical picture. Unfortunately, it was not mentioned what type of care was given at the research center. Also, to be able to quantify more clearly the changes that have occured it would be necessary to use a more objective type of behavior modifier. It should be noted at this point that while these last three studies suggest that serotonin is at a below normal level in hyperactive children, one study by Rapoport, et al. (1974) revealed no difference in platelet serotonin between groups of hyperactive and normal children. However, Yuwiler, et al. (1970) states that this method of platelet evaluation often produces inconsistencies.

EMG applied to hyperactivity. To further study this problem, it seems reasonable to use as a more quantifiable behavior modifier, some form of biofeedback regulation that would alter a certain behavior and then allow examination of physiological changes as well as other behavioral aspects that occur in conjunction with the behavioral change. Electromyographic feedback training has been shown to increase general skeletal muscle relaxation (Budzynski, 1977). EMG feedback has been applied to hyperactive children with mixed success. T. Anderson (1975) showed that hyperactive children could learn to "relax" with EMG feedback as measured by the biofeedback instrument. However, this was not shown to carry over to classroom behavior as shown by a behavior check list. It is possible that this was too broad of an application for only a small amount of biofeedback training. And, again, could be confounded by the fact that some may have reacted negatively to the treatment. Braud, et al. (1975), using a single subject design, was able to reduce tension both immediately after and between EMG training in a 6½ year old hyperactive child. Parent observation of the child also revealed that overall behavior had improved due to the EMG training. A more comprehensive study done by Braud in 1978 was quite dramatic in showing that EMG feedback could be very helpful in improving a variety of symptoms in hyperactive children. When comparing a group of diagnosed hyperactive children (N=15) to a group of non-hyperactive children (N=15) it was found that "the hyperactive children possessed significantly higher ($p<.002$) muscular tension levels and, in addition, presented more behavioral problems and had lower test scores" (p. 69). Then when two experimental groups of hyperactive children received biofeedback or progressive relaxation, a significant reduction of tension as measured by the EMG machine was revealed. Along with the reduction of tension there was a corresponding improvement of behavior as measured by a parental behavioral rating scale as well as improvement on both a "digit span subtest" and a "coding subtest". While the biofeedback group was better at reducing tension levels there was no difference in the amount of improvement in behavior between the groups.

However, both groups were significantly better in all areas than the hyperactive control group. It should also be noted that there was no difference within any of the groups between medicated and nonmedicated subjects as to their tension levels through the study; it was shown that nonmedicated subjects showed significantly greater improvement on behavior as measured by a combined behavioral rating scale.

Relationship of parameters. EMG feedback is shown, then, to affect behavioral aspects of individuals including hyperactive children. Evidence that it can also alter other nonbehavioral variables such as general or specific bodily systems is put forth by Stoyva (1977) and Budzynski (1969). Stoyva sites examples of research that reveals that GSR and heart rate changes are smaller for subjects who have received EMG training and are exposed to a stressor than are control subjects who are exposed to the stressor alone. Budzynski has shown that cortical changes occur with EMG training which is demonstrated by a lessened ability to discriminate paired flashes of light--a sign of decreased cortical arousal (Venables & Wing, 1962). Sittenfeld, Budzynski and Stoyva (1976) have shown that muscle relaxation training is a useful prelude to the induction of EEG theta rythms, a drowsy condition. Because serotonin is directly involved with various "transmissions" in the nervous system (Patton, et al., 1976), alteration of general arousal should alter total body serotonin levels.

Since blood serotonin levels may possibly be altered by a reduction of hyperactive behavior (Coleman, 1971), EMG feedback would seem to serve very well as a quantifiable behavior change method that would allow for a more exact analysis of the relationship between the two parameters. However, an EMG analysis would only correlate tension with the level of blood serotonin (or 5-HIAA in the urine), and would not reveal the changes in other behaviors such as attention span and gross motor activity. To further examine this relationship a further test must be included that measures attention span and motor activity.

Therefore, since EMG feedback has been shown to decrease tension and improve overall behavior of hyperactive children, it is hypothesized that successful EMG feedback will reduce the activity level, and increase the attention span of hyperactive children as measured by the technique of Hutt, et al. (1963), (see methods section). Furthermore, in relation to this improved behavior, as well as decreased muscle tension (as measured by the EMG machine), there should be corresponding changes in the level of serotonin in the blood as reflected by 5-HIAA urine concentration. 5-HIAA levels, then, are expected to rise to a more "normal" level.

METHOD

Subjects

Four children participated in the study. Their ages ranged from 8.1 years to 11.5 years (mean age of 9.6 years). There was one female ("subject A") and three male ("subjects B, C, and D"). All subjects had been diagnosed as hyperactive by at least one physician who was familiar with the etiology of hyperactivity. Three of the subjects had also undergone extensive testing at a large medical center in either Salt Lake City or Denver. All three exhibited very slight and nonspecific EEG abnormalities; two of these showed definite visual or visual-motor problems along with some facial "twitching". Two of the subjects were adopted.

Some special assistance had been or was being given in the school to all four children. However, none were in special education, nor had they been classified as "learning disabled". An attempt was made to keep medication dosages constant throughout the study. Medications and treatments were as follows: subject A, 15 mg of Rittalin (methylphenidate) in the morning and afternoon; subject B, 37.5 mg of Cylert (which was discontinued on the 8th day) and was put on 5 mg of Dexedrine (dextroamphetamine) per day on the 12th day (which was increased to 10 mg per day on the 16th day of the experiment); subject C was not put on any medication, and was being treated with a low sugar diet; subject D, 15 mg of Dexidrine per day.

Apparatus

For the EMG feedback training and EMG monitoring an Autogen 1700 electromyographic feedback analyzer was used. Muscle electrical activity is measured in integral average microvolts, i.e., the area under the curve of the EMG waveform. This is a significantly more accurate indicator of overall muscle tone than peak-to-peak EMG measurement. The bandpass selector was set at 100-200 Hz. This bandpass allows for good artifact rejection and exhibits especially good signal-to-noise ratio, permitting the monitoring of very low microvolt levels. During training sessions, the feedback consisted of a tone which pulsates at a steady rate while the pitch varies in logarithmic proportion to the EMG level. The tone rises in pitch as the EMG level increases and falls in pitch as the EMG level decreases. An audio feedback threshold was set at the average value that was obtained during baseline. When activated, the feedback threshold determines the maximum absolute level of EMG activity required for any of the audio feedback signals to be present.

EMG activity from the Autogen 1700 was relayed to an Autogen 5600 data aquisition center. This instrument allows for instantaneous and continuous readings of average EMG amplitude. Each 30 seconds a cumulative average value is given; at the end of 20 minutes a total average and standard deviation is given.

Procedure

For this study an ABAB single case design was employed as described by Hersen and Barlow (1977). Prior to the beginning of the procedure all of the parents and children were interviewed and familiarized with the experiment. Each child was brought through the whole sequence of events and each procedure was explained in detail.

Instructions were repeated at the beginning of each week.

EMG procedure. Beginning on Monday, at a designated time each day after school, each child participated in a week (five days) of baseline sessions with no feedback (see figure 2). The following week (after a weekend break) consisted of EMG with feedback. The EMG electrodes were attached to the forehead over the frontalis muscles. Relaxation of this muscle group had been shown to affect total relaxation and decreased cortical arousal (Budzynski, 1977). Each child was instructed to "reduce muscle tension by keeping the tone on" (i.e. below threshold). They were also told that relaxing their whole body and sitting very still would assist in keeping the tone on. In the next two weeks the same procedure was repeated.

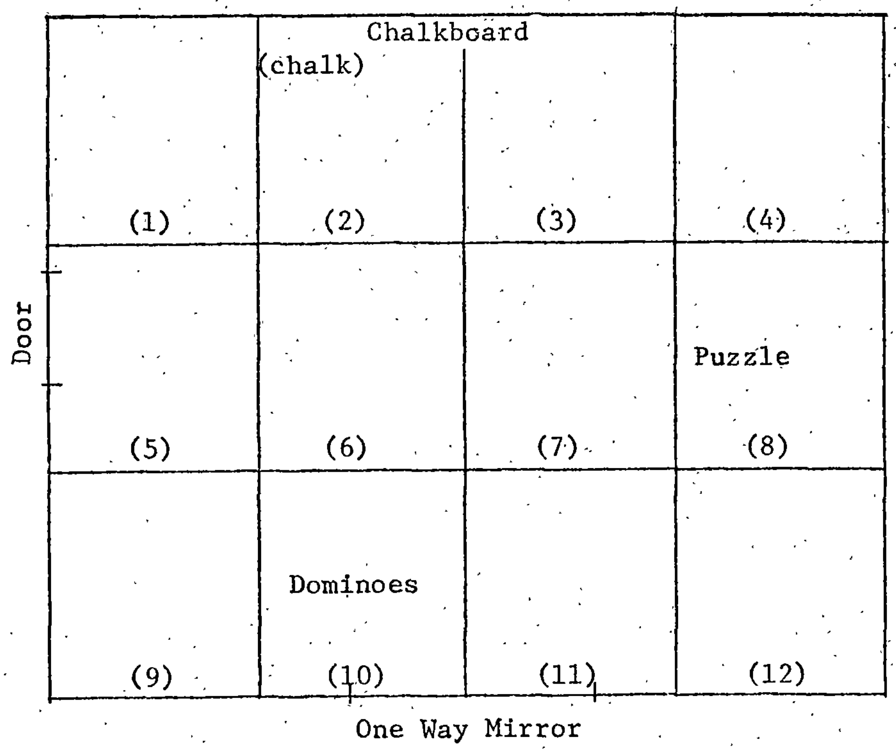
Activity level analysis. The method used to measure attention span and activity level has been described by Hutt, Hutt, and Ounsted (1963). This method was shown to be useful in objectively measuring activity level and attention span. This procedure involved placing the child in a small room (10x8), with a "grid" of 12 squares marked on the floor, for five minutes. This was done just prior to the EMG session so that any carry over from the preceding day's treatment could be ascertained. The room was unfurnished except for three "toys" that were placed in different parts of the room. The toys included a box of dominoes (square ten), a small puzzle of the United States (square eight), and a large blackboard which was situated opposite the one-way mirror (see figure 1). By watching through the one-way mirror, it was observed which square the child was in and a verbal note was made on a tape recorder as to each square that the child "visited". Also, a short phrase was used to describe the onset of various actions and directions of gaze. After the session, the tape was played back and a measurement was made as to the number of "new attentions" (as described by Hutt, et al.), as well as the number of squares visited. The onset and end of all attention spans were recorded and the time for each span calculated. From this an "average attention span" was calculated for each session.

Urine analysis for 5-HIAA. Beginning three days prior to the first day of the session and lasting throughout the experiment, all subjects were placed on a low serotonin diet (including precurser substances). At the end of each session a urine sample was obtained. A small amount of urine (.5 ml.) was "preserved" with 1 ml. of sulfuric acid immediately afterward, and was placed in the refrigerator overnight. The following day a quantitative test was run according to the procedure described by Natelson (1971) to determine the amount of 5-HIAA in the urine.

RESULTS

Values obtained on all variables: EMG muscle tension (microvolts), levels of 5-HIAA in the urine (mg/100 ml), average attention span (seconds), and number of squares visited ("squares") were plotted for

Figure 1: Diagram of Activity Observation Room



each subject (Figures 2-5). Also, values obtained for each individual are shown in Tables 1-4. Inspection of the means for combined baseline versus combined feedback treatments reveals that all four subjects showed changes in the direction of the hypothesis for EMG tension and 5-HIAA levels. Three of the subjects showed changes in the direction of the hypothesis in average attention span, and two subjects for the number of squares visited during a five minute period.

The Wilcoxon matched-pairs signed-ranks test (Siegel, 1956) was used to compare between baseline and feedback sessions. This test is a nonparametric test which is not dependent on the assumption of serial independency. All four subjects attained significant reduction ($p<.025$) of tension during feedback sessions. Subjects A and B showed significant increases ($p<.01$) of 5-HIAA levels in their urine during the two weeks of feedback sessions. Average attention span increased significantly for subjects A and D ($p<.01$ and $p<.025$ respectively), while none of the subjects showed a significant reduction of the numbers of squares that were visited.

To examine the relationship of the variables, correlation tests between each variable, for each individual, were conducted (Tables 1-4). Of the six correlations examined, four of the comparisons reached significance in at least one child. Significant correlations were not reached between EMG and average attention span, or 5-HIAA and number of squares, in any of the children. All four subjects

Figure 2: Levels of Variables for Subject A