The present award-winning high school student paper reviews the history of positive outcomes for biofeedback/neurofeedback interventions with many common disorders, especially attention-deficit hyperactivity disorder, epilepsy, and seizures, and discusses one report suggesting the potential of biofeedback for autism spectrum disorders. The student researcher recruited an adolescent male with autism spectrum disorder and obtained a pretreatment score on a parent questionnaire, the Autism Treatment Evaluation Checklist (ATEC), measuring four categories of autism-related behaviors. The student researcher developed an innovative general biofeedback treatment regimen, designed to guide the trainee to relax and self-soothe. The regimen included self-ratings of calmness on a 10-point Likert-type scale, temperature training with biodots, breath training with a home training device, additional temperature training with a handheld digital thermometer, use of a biofeedback game using electrodermal and heart rate measures, and a final meditation exercise. The adolescent completed 18 sessions in 6 weeks and showed significant improvement in self-reported calm, increased hand temperature with stress dots, a slowing in breath rate, hand warming using the digital thermometer, improvements in skin conductance, and a lowering of heart rate into the relaxation range. Most significantly, the final parent rating on the ATEC showed measurable improvement on sensory/cognitive awareness and health/physical behavior and dramatic improvement in sociability, a core feature of autism spectrum disorders. This positive outcome supports the need for additional research applying biofeedback to autism spectrum disorders.

Introduction
Biofeedback is the act of showing someone (the participant) recordings of one or more of his or her physiological systems in real time, as those recordings are being made (e.g., measurements of localized muscle tension, hand temperature, respiratory rate). This permits the participant to be instantly and continuously aware of the level of physiological system functioning and any subsequent changes in the level of such system’s functioning. The participant can then use this real-time information to increase his or her overall awareness of bodily system functioning and the physiologic cues that are associated with such bodily system functioning. In biofeedback therapy, designed to alleviate particular symptoms of illness, the participant is taught to recognize and then to effectively use the physiologic cues associated with less than optimal physiologic system functioning by making behavioral changes (e.g., slowing the breathing rate) that are likely to restore optimal physiologic system functioning for the given circumstance (e.g., to alleviate pain associated with a migraine headache).

During the past 30 years, many studies have been conducted to gauge the efficacy of biofeedback and neurofeedback. A majority of these studies have indicated that through rigorous biofeedback exercising, one can facilitate improved brain performance and/or mitigation of physical ailments. The research centered mainly on physical/mental injuries or disorders, such as anxiety, attention-deficit disorder (ADD) and attention-deficit/hyperactivity disorder (ADHD), chronic and bodily pains, headaches/migraines, hypertension, irritable bowel syndrome, digestive disorders, alcoholism, asthma, and insomnia.

Alhambra, Fowler, and Alhambra (1995) explored the possibility of using biofeedback as a treatment for ADD. The researchers explained that ADD is generally treated with stimulant medications such as Ritalin, which has short-term positive effects and many unwanted side effects, including insomnia and a loss of appetite. Those surveyed in the study were biofeedback patients, all of whom had already completed a minimum of 30 sessions as a treatment for ADD (Alhambra et al., 1995). The study’s evaluation of the effectiveness of the biofeedback sessions was based on questionnaires filled out by the parents or guardians of the patients. These questionnaires asked for responses
regarding the child’s symptoms, medical history, scholastic performance, conduct, and social behavior before, during, and after the biofeedback treatment. The study found that 86% of the participants showed significant clinical improvement in their ADD conditions upon the completion of the biofeedback treatment, 74% showed significant academic improvement, and 77% of the children on medication were able to be taken off or given decreased medication upon the treatment’s conclusion. The authors of this study indicated that their results clearly established biofeedback as an alternative to the pharmaceutical treatments for ADD. It is fair to conclude that this study demonstrates that children and young teenagers with ADD can greatly benefit from biofeedback training.

A similar study by Lubar, Swartwood, Swartwood, and O’Donnell (1995) evaluated the effectiveness of electroencephalography (EEG) neurofeedback training for ADHD in a clinical setting as measured by changes in psychological test scores and behavioral ratings. The study included 23 participants ranging in age from 8 to 19 years, all of whom participated in a 2- to 3-month summer program of concentrated neurofeedback training (Lubar et al., 1995). Changes in mental activity, academic performance, and behavior (based on a specified rating scale) were evaluated. Part I of the study showed that participants who decreased slow brain-wave activity showed significant improvement in relief of their symptoms. Part II indicated significant improvement in behavior ratings based on parental assessment, and Part III indicated significant increases in academic performance following neurofeedback training (Lubar et al., 1995). The authors’ conclusion emphasized that biofeedback has the potential to be a valuable treatment option for children and adolescents suffering from ADD/ADHD.

Andrews and Schonfeld (1992) used EEG biofeedback with a sample of 83 patients drawn at random from the population of those suffering from uncontrolled seizures on a regular basis. The study yielded the important finding that whereas 60% of people with epilepsy still experience seizures despite drug therapy, total seizure control through biofeedback was achieved by 83% of the total sample population (Andrews & Schonfeld, 1992). Furthermore, even those individuals with extreme cases, suffering from daily seizures when treatment started, cited 67% success. These results suggest that not only can biofeedback therapy be highly effective in treating disorders normally treated with conventional medications, but biofeedback can even surpass the effectiveness of prescription drug therapy in certain cases.

Unlike the previously referenced studies, the study by Linden, Habib, and Radojevic (1996) included a control group. The basis for judging the efficacy of the EEG biofeedback sessions was an IQ test and parent behavior rating scales for inattention, hyperactivity, and aggressive/defiant (oppositional) behaviors, measured at pretreatment and posttreatment. The experimental group received 40 biofeedback sessions, with a duration of 45 minutes per session over a period of 6 months. The control group had no biofeedback or any other psychological treatment/medication. At posttreatment, the experimental group demonstrated a significant increase at a mean of 9 points in their IQ scores as compared to the control group’s increase of just 0.05 points. The experimental group also significantly reduced inattentive behaviors as rated by parents in comparison to the control group. This study suggests that biofeedback positively affects children with ADD/ADHD, especially compared to those children who do not undergo any such treatment.

Although there has been some research to assess the utility of neurofeedback techniques in mitigating common symptoms associated with autism spectrum disorder, a review of the literature indicates that very little research has been conducted to assess whether conventional biofeedback practice has any such efficacy. In a recent neurofeedback study conducted at the University of California, San Diego, researchers were able to identify a link between autism and a mirror neuron dysfunction. The study indicates the following, referenced here for its relevance to the proposed study: “One therapeutic possibility suggested by the study’s findings is biofeedback” (Obermana et al., 2005). Given the history of successful treatments achieved by biofeedback in other fields and information indicating the possibility that individuals diagnosed with autism may respond positively to biofeedback, I believe that a study gauging the effects of a regular regimen of conventional biofeedback training on a participant diagnosed with an autism spectrum disorder could contribute important information to the research community and serve to highlight needs for further research in this area.

Methods

This is a case study of an adolescent male diagnosed with autism spectrum disorder. The study is being carried out with the goal of helping the participant to self-soothe by learning to effectively use conventional biofeedback techniques, thereby lessening his need to express frustration through socially unacceptable behaviors. The hypothesized outcome is that after 18 sessions over a 6-week time period of biofeedback therapy, the participant will evidence measurably improved behavior.

The first part of the research assessment uses a social and behavioral scale/report, filled out by the mother of the participant pretreatment, at intervals throughout the
treatment, and posttreatment. This behavioral scale serves as the key in determining whether there is a correlation between the participant’s learning to relax and self-soothe through biofeedback training and his autistic symptoms. The behavioral scale, called the Autism Treatment Evaluation Checklist (ATEC), was developed by the Autism Research Institute and is specifically designed to assist researchers in evaluating the efficacy of treatments administered to children with autism (see Appendix 1). This scale measures any improvements within four categories of specified behaviors and differs from previous scales/tests, which were instruments primarily designed to diagnose autism rather than to measure gradations of symptom improvement. This ATEC scale measures the improvements in the areas of speech/language/communication, sociability, sensory/cognitive awareness, and health/physical/behavior. After being filled out, the ATEC report was submitted to the Autism Research Institute for immediate evaluation and scoring in overall and subcategories. This case study took place over 6 weeks, with approximately three 1-hour sessions per week.

The protocol of each biofeedback treatment was identical and involved the following: First, the participant was asked to label on a scale (ranging from 0 to 10) how calm he feels, with 0 (accompanied by the color blue) being the most calm and 10 (accompanied by the color red) being the most anxious. Next, the participant used stress dots, which measure stress based on a color scale assigned to hand temperature. This took approximately 5 minutes, and through breathing/relaxation techniques, the participant was supposed to learn how to relax and decrease stress.

Next, the participant used a tool called RESPeRATE, which uses unique breathing exercises and a monitor that measures breaths per minute, as well as a soothing musical accompaniment that plays at a speed corresponding to the user’s breath rate. This tool enables the participant to slow his breathing rate from the normal range of 14 to 18 breaths per minute to the therapeutic pattern of fewer than 10 breaths per minute with prolonged exhalation. The participant used the RESPeRATE tool for 10 minutes.

The participant then used the SC911 digital thermometer, which gauges and helps manage stress by displaying hand temperatures during biofeedback training. This tool works via a sensor, which is placed on the dominant finger of the nondominant hand.

The initial temperature was recorded, followed by documentation of hand temperatures every minute for 5 minutes while the participant used the biofeedback breathing techniques.

For the next 30 minutes, the participant played biofeedback games using biofeedback software made by Somatic Vision. This software, called Inner Tube and Particle Editor, uses a new biofeedback hardware device that measures skin conductance level (SCL) and heart rate variability (a measurement of cardiovascular health that measures the heart’s ability to adapt to changing circumstances) through three finger sensors that are gently attached. The measurements were registered through the hardware and fed back to the participant through biofeedback activities on the computer screen. These biofeedback games are designed to maintain the participant’s attention and promote the participant’s ability to use biofeedback skills while also producing six physiological measurements that are recorded and compared throughout the treatment.

The final component of each session was 10 minutes of meditation, guided by a biofeedback meditation audio CD. The participant also practiced biofeedback and breathing skills with this CD (with the assistance of his parent) once a day for 10 minutes for the duration of the study. The participant was aware that sessions could be ended early and/or the protocol could be amended in terms of length or number of sessions if it became apparent that he displayed any discomfort.

Results
The pretreatment ATEC report filled out by the participant’s parent indicated an overall score of the severity of the participant’s autistic symptoms of 28 (the higher the score, the greater the participant’s impairment). The overall score is calculated by cumulatively adding the four subcategory scores. This value did not vary significantly the next week (score of 29) but drastically improved to 22 and even further to 18 in Reports 3 and 6, respectively (see Figure 1). The posttreatment overall score (12/20) was also 18. A paired t test in which the pretreatment and 1st week overall ATEC scores were compared to the final week and posttreatment overall ATEC scores showed the two-tailed p value to be .0303. The p value (.0303) is lower than the 5% alpha level of significance, and thus, the null hypothesis is rejected.

The most substantially affected area was sociability, which improved by seven levels (13 to 6) from the pretreatment ATEC report to the posttreatment ATEC report (see Figure 2).

Speech/language/communication did not seem affected by the treatments and fluctuated between Reports 1 and 2 in all eight ATEC reports. Sensory/cognitive awareness, though regressing in Report 2, eventually improved as compared with the pretreatment value (9) to 7 in Reports 5 through 7 and the posttreatment report (see Figure 2). The health/physical/behavior also improved from a value of 5 in the first two reports to a value of 4 in Reports 3 through 7 and the posttreatment report (see Figure 2).
Although the ATEC report looks for trends in the child’s general symptoms, data from each session were collected to measure improvement during the biofeedback therapy. The following data were gathered for the purpose of judging whether each individual biofeedback exercise was having its intended result on the participant.

The participant’s self-assigned calmness level (in which the participant is asked to label on a scale from 0 to 10 how calm he feels; see Appendix 2 to view the scale) improved from the presession to the postsession during each of the 18 sessions (see Figure 3).

The stress dots measurements, which are based on a color scale assigned to hand temperature while the participant practices breathing/relaxation techniques aimed at helping the participant learn how to relax and decrease stress, improved/increased in level/hand temperature to the optimal levels of either 6 (calm, 90°F to 92°F) or 7 (very relaxed, greater than 92°F) presession compared to postsession during each of the 18 sessions (see Figure 4).

Next, the RESPeRATE tool, which promotes the slowing of the participant’s breathing rate, yielded results that show that the participant successfully lowered his breathing rate from the normal range of 14 to 18 breaths per minute to the therapeutic pattern of fewer than 10 breaths per minute in all but the first session of the study (see Figure 5).

The SC911 digital thermometer, which gauges stress by displaying hand temperatures for the participant during biofeedback training, showed that the participant’s hand temperature/calmness increased several degrees to at least 95°F to 96°F during all but 1 of the 18 sessions (see Figure 6).

The results gathered while the participant played the biofeedback software games included measurements of SCL, which indicates increased sympathetic nervous reaction (the more one sweats, the better the conductance), and heart rate variability (periodic recording of heart rate to measure cardiovascular health in terms of the heart’s ability to adapt to changing circumstances). These recordings show that throughout the treatment, the participant’s SCL consistently increased/improved during each session and his heart rate variability also consistently improved and was lowered into the normal/relaxed range of about 70 beats per minute (bpm) during each session (see Appendices 3 and 4).

Discussion

The study showed a measurable relationship between conventional biofeedback therapy and the mitigation of several common symptoms associated with autism spectrum disorder. The pretreatment ATEC report rated the participant’s overall autism symptom severity score at 28, and the 2nd week’s ATEC report value did not vary considerably, indicating a score of 29. However, the overall severity scores exhibited substantial improvement as the participant’s scores improved to 22 and 18 in Reports 3 and 6, respectively (see...
Figure 1). A paired t test in which the pretreatment and 1st week overall ATEC scores were compared to the final week and posttreatment overall ATEC scores shows the two-tailed p value to be .0303. The p value (.0303) is lower than the 5% alpha level of significance, and thus the null hypothesis is rejected. Therefore, the improvement in overall ATEC scores is statistically significant. Thus, it is reasonable to conclude that the four indicators of behavior, as measured by the ATEC, showed improvement from pretreatment baseline measurements as a result of the biofeedback treatments and the daily program of meditation practiced by the participant.

Although improvement was noted in the categories of sensory/cognitive awareness and health/physical/behavior, the sociability category has proven to be the most intriguing of all the categories. The participant’s improvement from level 13 to 6 (pretreatment ATEC report to the posttreatment ATEC report) might indicate that conventional biofeedback’s most positive effect as a treatment modality for persons with autism spectrum disorder may be in the area of sociability (see Figure 2).

The participant’s session indicators displayed results that showed that he was positively responding to the exercises. This means that the exercises served as biofeedback efficacy indicators and that his responsiveness to the exercises (such as the increased hand temperatures, improved SCLs and heart rate variability, and lowered breaths per minute) proved that the conventional biofeedback exercises were having their intended calming/relaxing affects on the participant.

The fact that we have achieved a statistically significant result in support of the hypothesized outcome strongly suggests that conventional biofeedback treatments, combined with a regular daily program of meditation exercises, may serve to mitigate certain common symptoms associated with autism spectrum disorder. Validation of our hypothesis is particularly noteworthy because others studies have only alluded to the possibility of such a therapeutic connection. This study demonstrates that, at least in this case, with this adolescent male participant, such a connection exists. This outcome surely points to the need for further study in an effort to replicate these findings with a larger cohort (see Conclusion section). This can readily be accomplished by researchers and health care providers involved in mainstream autism treatment and care because the treatment protocol used in this study was entirely noninvasive and met with no resistance from the participant who accepted treatments in a positive and enthusiastic manner (his mother reported
that he looked forward to the hourly biofeedback sessions and always reminded her each day that it was time for him to practice the meditation exercises). In addition, the equipment used does not require an extensive budgetary outlay.

**Conclusion**

This study’s findings strongly suggest that conventional biofeedback therapy may be an effective treatment option to mitigate certain symptoms associated with autism spectrum disorder (especially symptoms that fall under the category of sociability). Because of the sensitive population of interest, a closely monitored study with a larger cohort is needed to evaluate whether the findings will generalize to other individuals with autism spectrum disorder. The next step is to replicate this study with a larger and coordinated group, which may more effectively demonstrate whether conventional biofeedback therapy mitigates symptoms associated with autism spectrum disorder in the context of the autistic population as a whole.

**Appendix 1. Autism Treatment Evaluation Checklist report.**

**Appendix 2. Calmness scale.**

Do You Feel Calm or Nervous?

Nervous

Calm

10  9  8  7  6  5  4  3  2  1  0

**Appendix 3. Skin conductance level recordings.**

**Appendix 4. Heart rate variability in breaths per minute.**
References


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