Oral Presentation

Use of Auditory and Visual Stimulation to Improve Cognitive Abilities in Learning-Disabled Children

by

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INTRODUCTION TO LEARNING DISABILITIES

Children with learning disabilities make up a significant number of the population, and the diagnosis of LD appears to be increasing. Currently, 6,195,111 disabled individuals between birth and age 21 are being served under the Individuals with Disabilities Education Act. This number is based on enrollment in public schools (pre-kindergarten through 12th grade), and translates into approximately 13.2 % of the U.S. population. These numbers include all types of disabilities and not solely those children diagnosed with learning and attentional disorders.

Some specific cognitive weaknesses of learning disabilities include information processing, short-term memory, and encoding These cognitive deficits can be lifelong, and research demonstrates that the long-term effects of LD place these individuals at a high risk for emotional and social difficulties, and can often result in antisocial behaviors and later psychological disorders. Some studies suggest that individuals with learning disabilities are also at a significantly higher risk for substance abuse than non-learning-disabled individuals.

INTERVENTIONS FOR LEARNING DISABILITIES

The most common treatment interventions for learning disabilities are specialized academic instruction to strengthen cognitive weaknesses, parent training, behavioral therapy, and psychostimulant medications to address comorbid behavioral problems .The use of stimulant medication addresses the various attentional and behavior symptoms, but gains in long-term academic achievement have not been substantiated. It is unfortunate that some children cannot receive such treatment due to lack of insurance, cost of medication, difficulty with compliance, and aversion to pharmacological intervention.

With mounting evidence that individuals with learning disabilities can have a high risk of developing long-term problems such as delinquency, drug abuse, and personality disorders, as well as continuing functional deficits and psychopathology into adulthood, it is important to look to early intervention to decrease such later life risks.

AVS AS TREATMENT FOR LD

This study examined the effects of auditory and visual stimulation (AVS) on children diagnosed with learning disabilities who demonstrated low and below average scores on the Wechsler Intelligence for Children-Third Edition SCAD profile to determine if such a treatment intervention may improve some of the cognitive weaknesses common to those diagnosed with these disorders. This study investigated the application of auditory and visual stimulation (AVS) for the cognitive weakness of children diagnosed with LD as measured on four subtests of the WISC-III (Symbol Search, Coding, Arithmetic, and Digit Span) and 2 Indices (Freedom from Distractability and Processing Speed). This study also analyzed any relationships among the older and younger groups and the six subtest variables.

PREVIOUS STUDIES USING AVS FOR TREATMENT OF LD

Though some promising studies have used AVS as an intervention for learning disorders, there are no recent studies using the newest technology to address some of the core weaknesses in those individuals diagnosed with learning disabilities. An early study by Carter and Russell (1993) administered up to 80 AVS sessions over 8 weeks to students with LD, and found significant increases in scales measuring memory, reading, and spelling, as well as in overall verbal IQ scores. A later study using by Patrick in 1994 used 15 individual photic-driven EEG neurotherapy sessions with children diagnosed with attention deficit hyperactivity disorder (ADHD), found improvements in the WISC-III Processing Speed and Freedom From Distractability indexes. Recent studies by Joyce & Siever in 2000, and Micheletti in 1998, used AVS sessions at varying frequencies for the treatment of ADHD and found improved standardized test scores, a decrease in problem behaviors, and overall improvement in academic performance. These studies suggest that AVS may be a viable method for enhancing cognitive functioning in children diagnosed with learning disabilities and attentional problems.

This current study used auditory and visual stimulation technology at faster light flickering frequencies to investigate if significant changes in cognitive abilities could occur in only 12 applied AVS sessions. This study investigated six weaknesses known to children diagnosed with learning disabilities, which include encoding, sequencing, numerical ability, visual motor speed and accuracy, and short-term memory.

THE COGNITIVE WEAKNESSES IN LD

The specific cognitive abilities measured in this study were chosen as the current definition of learning disabilities by Hammill(1993) suggests that their etiology involves deficits in basic cognitive functions that are developmentally related to central nervous system dysfunction. Substantial evidence supports this theory, and it is commonly agreed that such deficits specifically stem from weaknesses in executive functions, including working memory, encoding, visual-motor coordination, attention and response inhibition, planning, and processing.

DIAGNOSES OF LD

The diagnosis of a learning disability involves the use of standardized testing measures such as achievement and intelligence quota (IQ) tests. The Wechsler Intelligence Scale for Children-Third Edition is commonly used to assess verbal and performance IQ scores to obtain a full scale IQ score. Verbal IQ is a measure of an individual’s verbal comprehensive abilities, while the performance IQ is a measure of perceptual organizational skills. Typically, a specified discrepancy between the verbal and performance IQ test scores are considered an indicator of a learning disorder.

MEDICATION AS TREATMENT FOR LD

While educational remediation addresses cognitive weakness in children with LD, stimulant medication is sometimes used to decrease some of the attentional and behavior difficulties associated with learning disabilities. It is commonly agreed that stimulant medications can cause changes in the neuroendocrine systems, which can have a calming effect on hyperactive behaviors and attentional difficulties. Other findings suggest that neurological dysfunction could be improved through the regulation of hyper and hypo aroused brainwave states through the use of brainwave training. Investigation involving the brainwaves of those with LD/ADHD suggested faulty regulation of brainwave activity and nervous system arousal as central to the understanding of these disorders.

EEG NEUROFEEDBACK AS TREATMENT FOR LD

Through some of these discoveries, the use of electro-encephalography (EEG) neurofeedback evolved (a method by which the brainwave activity is reflected back to the participant via computer technology) to help improve symptom control and aid in the regulation of brainwave activity. Researchers have found that EEG neurofeedback with individuals diagnosed with attentional disorders has shown an increase in the control of behavior problems that accompany learning disorders. The current study was conducted based upon such findings, which implicate abnormal brainwave states and decreased neuronal activity in individuals with learning disorders.

THEORETICAL SUPPORT OF THIS AVS Study1THEORETICAL SUPPORT OF THIS AVS Study:

Effects of Light Stimulation in Animal and Human Studies1Effects of Light Stimulation in Animal and Human Studies

Early studies found that electrical stimulation administered to the frontal cortex in animals demonstrate significant enhanced recovery of neurons in the visual cortex, suggesting increases in visual input processing and improved attention paid to external stimuli (Spinelli & Pilbram, 1967). Diamond (1988) discovered that challenging environmental stimulus result in increases in dendritic growth, brain weight and density, as well as changes in molecular, synaptic, and behavior in animal studies resulting in increased memory and maze learning. Later, many studies found greater dendritic length and structural changes in the cortex of postmortem humans who had lead more challenging lives.

Neurobiological studies have discovered a reduction in brain activation, neurological delays, cerebral asymmetry, and decreased cerebral metabolism within the prefrontal and premotor region within the frontal lobe of LD/ADHD participants. An early study demonstrated that photic driving was associated with increased brain glucose uptake and blood flow. Other studies found photic stimulation caused an increase in lactate in the human visual cortex, increasing glucose levels in the brain.

Sappey-Marinier et al. (1992) concluded that these changes may result in increase brain metabolism and brain lactate concentrations. Singh et al (1991) demonstrated that auditory and visual simulation resulted in stimulation of the cerebral cortex.

ENTRAINMENT FOR LD

Induction into certain brainwave states has been found to increase or decrease brain activity through the “entrainment” process. “Entrainment” is a process that occurs when brainwave activity falls into a specific cadence or rhythm through the use of repetitive and recurrent presentation of light and sound pulses. Brainwave entrainment through the use of auditory and visual stimulation (AVS) affects electroencephalographic (EEG) output (a measure of brainwave activity), and can result in the suppression or enhancement of specific brainwave frequencies. Studies supported evidence that changing the cerebral electrical activity associated with LD/ADHD improved symptoms and enhanced cognitive performance. Light or photic driven EEG neurotherapy found improved regulation of irregular or over aroused/under aroused brainwave states which affect learning and attending, yielding in increased neuroactivation.

WHAT IS AVS?

Auditory and visual stimulation (AVS) is a method of brain stimulation and brainwave "entrainment" that is applied through the ears and optic nerves by means of headphones and specially designed glasses inset with white light-emitting diodes (LEDs). These lights flash at predetermined frequencies, and are coupled with binaural tones that are received by the individual through headphones. The auditory and visual stimulation are typically synchronized with each other, but can be varied depending on the treatment protocol or desired effect. The light emitting from the glasses and rate of the flickering affect the brain through the optic nerve, and cause the brainwaves to "entrain" or match the rate of flickering to a desired frequency, depending on the preferred outcome. The external flicker of light at specific frequencies have been found to induce the brainwave activity to fall into specific frequencies by becoming entrained or synchronized. The method by which this "entrainment" occurs is known as Frequency Following Response (FFR). Unlike EEG biofeedback where the object is for the user to deliberately try to calm or train brainwave activity, AVS induced "entrainment" occurs directly in the brain without any conscious effort. The Frequency Following Response is also known as the "flicker phenomenon" because of the brain's ability to reproduce or synchronize with the same rhythm as the external flashing light. Some findings demonstrate that not only does the area in the brain associated with sight become synchronized with the external flickering lights, but the entire cortex of the brain demonstrates changes toward the same frequency of the flashing lights.

Because induction into certain brainwave states has been found to increase or decrease brain activity through the entrainment process, the implications of using AVS as treatment with children has been explored. Hyperactive behaviors and feelings of anxiety for example, have been found to decrease due to the reduction of high-arousal brainwave states. Other studies suggested that the application of auditory and visual stimulation may increase cognitive processes and enhance academic performance as demonstrated on standardized testing. A more recent study demonstrated improved behavior including impulsivity in ADHD children.

BRAINWAVES AND LEARNING WITH AVS

Various areas of the brain must communicate with each other to establish the basis of the assimilation of sensory information, sensorimotor coordination, and other brain functions that are necessary for learning, memory, information processing, behavior, and perception. Hebb (1949) theorized that such communication occurs through the formation and connection of cells whose synaptic linkages are strengthened as a result of the synchronous firing of activated cells. It has been only since the development of technologies such as EEG to demonstrate its existence that Hebb's concept has validity.

Studies have demonstrated that faster EEG activity in the gamma range (20-70 Hz) heightens during, and may be associated with, the formation of ideas and memory, linguistic processing and other abilities and behavioral functions. Miltner et al. (1999) demonstrated that increased gamma band activity was not only linked to associative learning, but they found that gamma band coherence also increases between regions of the brain that are receptive. According to Miltner et al. (1999), increased gamma activity is also connected to associated learning, and found that gamma band coherence expands between brain regions that takes in the two types of stimuli needed in an associative learning procedure. Hebb (1949) suggested that brain communication occurs when cells are activated and fire synchronously, strengthening synaptic linkages. Mitner et al. (1999) proposed that such a heightened coherence between the brain's regions may meet the requirements necessary for the formation of hebbian cell assemblies, linking and strengthening areas of the brain that are required to communicate together in order for associative learning to occur. Mitner et al. (1999) further suggest that coherence may be an indicator of associated and other types of learning.

CURRENT STUDY

Many of the previous studies using AVS targeted slower brain frequencies and numerous sessions (Carter & Russell, 1993, 1994; Joyce & Siever, 2000; Olmstead, 2000; 2001; Patrick, 1994). This research study targeted faster brain frequencies in the high beta and gamma range (20-40Hz) when applying auditory and visual stimulation based on studies finding that faster frequencies were associated with learning (Miltner et al., 1999; Singer & Grey, 1995; Singer, 1990). These studies suggest that brainwave coherence in the gamma range may increase and strengthen synaptic linkages through the synchronistic firing of activated neural cells.

STUDY PARTICIPANTS

The participants of this study were children diagnosed with learning disabilities . The children ranged in age from 6 to 16 years of age, and were from varying socioeconomic backgrounds. There was an over-representation of boys in this study (24 boys and 6 girls), which may be accounted for as there is a general over-representation of LD/ADHD boys to girls found in much of the literature. Study explanation and testing procedures were explained to both parents and children prior to signing a Study Consent Form and the administration of the WISC-III SCAD profile. The child was read the Child Assent Form as an explanation to the study.

Because of the wide variety of learning disorders, the principle qualifying factor chosen was the diagnosis of LD with low or below average scores of the WISC-III SCAD profile. Participants were screened to eliminate those with migraine or history of headache or head trauma, including seizure disorder or epilepsy, and concussion. Though the presence of a learning disability was the primary criteria for induction in the study, many children with some form of LD also were also diagnosed with ADHD. The diagnoses ADHD was based upon the criteria of the DSM- IV.

INSTRUMENTATION

The WISC-III SCAD profile was chosen as a measure as it is agreed that individuals with learning disabilities perform lowest on tasks requiring sequential processing, which is expressed in difficulties with planning, numerical ability, reading, and distractability. Research suggests that low scores on specific subtests of the WISC-III indicate weaknesses in executive abilities in which the individual experiences difficulty attending to stimuli while performing other mental tasks simultaneously. In children, the outcome of these cognitive deficits results in poor academic performance. Additionally, the SCAD profile was also chosen as it yields two additional factor scores, Freedom From Distractability (FFD) and Processing Speed (PS) indexes. Children with ADHD are found to score particularly lower on the FFD index.

The WISC-III SCAD profile was administered to each participant prior to undergoing 12 biweekly 35 minute AVS sessions. Upon completion of the 12 AVS sessions, the SCAD subtests were re-administered.

PROCEDURE

This study design was quasi-experimental with a convenience, nonrandom sample, and repeated measures, with no comparison group. After the initial screening and the signing of the Study Consent and Child Assent Forms, each participant was administered the SCAD subtests of the WISC-III. If the study criterion was met as measured by low or below average scores on the WISC-III subtests, systematic AVS treatment was administered 2 times a week for a total of 6 weeks. Participants put on headsets and light goggles and underwent AVS while reclining in a comfortable chair. Children were given the choice to listen to a story on cassette tape or compact disc while undergoing AVS. When the story was chosen and the light glasses and headphones were in place, the AVS session begun. All participants underwent 2 weekly AVS sessions. Each participant received one Excitatory and one Inhibitory session a week for 6 weeks, for a total of 12 alternating Excitatory and Inhibitory AVS sessions. Upon completion of the 12 AVS sessions, posttesting was administered using the WISC-III SCAD profile. Analysis was conducted using the Statistical Package for the Social Sciences (SPSS).

NULL HYPOTHESES AND DATA COLLECTION

Two types of analysis were used to interpret the test data. An analysis of variance **(**ANOVA**)** and a paired samples *t* test were used.

The first null hypothesis predicted that auditory and visual stimulation (AVS) would produce no significant difference (t test, $p < .05$) between the mean pre and posttest scores of the speed of information processing and visual-motor coordination as measured by the Symbol Search subtest of the WISC-III.

The second null hypothesis predicted that auditory and visual stimulation (AVS) would produce no significant difference (t test, $p < .05$) between the mean pre and posttest scores of information processing and visual-motor coordination as measured by the Coding subtest of the WISC-III.

The third null hypothesis predicted that auditory and visual stimulation (AVS) would produce no significant difference (*t test*, *p* < .05) between the mean pre and posttest scores of number ability and short-term memory as measured by the Arithmetic subtest of the WISC-III.

The fourth null hypothesis predicted that auditory and visual stimulation (AVS) would produce no significant difference (*t* test, *p* < .05) between the mean pre and posttest scores of short term memory as measured by the Digit Span subtest of the WISC-III.

The fifth null hypothesis predicted that auditory and visual stimulation (AVS) would produce no significant difference (*t* test, *p* < .05) between the mean pre and posttest scores of the ability to attend and concentrate as measured by the Freedom From Distractability (FFD) Index of the WISC-III.

The sixth null hypothesis predicted that auditory and visual stimulation (AVS) would produce no significant difference (*t* test, *p* < .05) between the mean pre and posttest scores of overall processing speed as measured by the Processing Speed (PS) Index of the WISC-III.

The seventh null hypothesis predicted that there would be no relationship between age and WISC-III subtest scores (*p* < .05).

The eighth null hypothesis predicted that there would no significant correlations among the dependent measures of Symbol Search, Coding, Arithmetic, Digit Span, FFD and PS of the WISC-III (*p* < .05).

Research questions 1 through 6 were analyzed with paired samples *t* tests to determine if there were significant changes from the mean pretest to the mean posttest of the six WISC-III subtest scales, including Freedom From Distractability and Processing Speed indexes. Research questions 7 and 8 were analyzed with the Pearson product moment correlation to determine if there were any relationships among the six variables.

The independent variable in the study was the AVS treatment. The WISC-III SCAD profile subtests, which emphasize the functions of speed of information processing, visual short-term memory, visual-motor coordination, and number ability and sequencing, acted as dependent variables, and are described as follows:

1. Visual-motor coordination, planning, encoding information in preparation for

further processing as measured by the WISC-III Symbol Search subtest.

2. Visual short-term memory and sequencing ability as measured by the Coding subtest.

3. Auditory memory, sequencing ability, concentration and attention as measured

by the WISC-III subtest Arithmetic.

4. Immediate rote recall, concentration and attention, auditory sequencing, and rote learning as measured by the WISC-III Digit Span subtest.

5. Ability to Attend as measured by the WISC-III Index Freedom From Distractability.

6. Speed of information processing as measured by the Processing Speed Index. The results of each WISC-III subtest were compared pre and posttest.

The seventh null hypothesis was that there would be no relationship between age and subtest scores, and compared the pretest and posttest mean scores of younger and older participants the WISC-III SCAD profile. The eighth null hypothesis was that there would be no correlation among the dependent measures (Arithmetic, Digit Span, Coding, Symbol Search, and the indexes Freedom From Distractability and Processing Speed) and a correlation of all the dependent measures was analyzed.

RESULTS

The hypotheses for the study were that AVS would not affect any of the specific cognitive abilities in learning-disabled children. The results of the ANOVA demonstrated significant gains in pretest to posttest means on all variables. The children were compared on all variables and on all measures the children made significant improvements (p = .00). See Table 1.

With regard to Null Hypothesis 7, both the younger and older groups of children when compared pretest to posttest on all correlated *t* tests demonstrated significant gains.

The younger children demonstrated more significant scores in all variables (p = < .00) with the exception of Arithmetic (p < .01). It appeared that the younger children made higher gains that the older children when compared at the .01 level. The younger participants scored most significantly (p< 0) in Digit Span, Coding, Symbol Search, FFD, and PS when compared to the older children in these subtests with the exception of Arithmetic (p < .01). The most notable difference between the younger and older groups was found in the Coding subtest, which measures psychomotor speed and sequencing ability. Coding subtest scores can be lowered by anxiety as well as depression, as the psychomotor slowing found in depressive states can produce a decrease in performance levels.

These results may be important when considering the age to begin AVE intervention in the treatment of LD. This researcher hypothesizes that younger children may make more significant cognitive gains early on due to brain plasticity (the ability of synapses to change as circumstances require). It has been well documented in many studies that during early development the brain is capable of reorganizing patterns and systems of synaptic connections in ways that an older brain cannot.

Another factor that may account for younger children making more significant gains may be due to a lower incidence of behavioral difficulties or self-esteem issues that may have not yet developed with regard to difficulties with learning.

The second least significant score in comparison to pre and posttest means was found in the FFD index. Younger children demonstrated significant differences pre- and posttest in FFD (p < 0), whereas the older group demonstrated less significant change pre and posttest (p < .07). Freedom From Distractability Index is believed to be lowered by anxiety and poor motivation, thus the posttest means of the older group of children may also reflect less change due to either emotional difficulties or the brain's inability to respond as well as the younger group (p < 0).

Finally, Null Hypothesis 8 was rejected due to the highly correlated scores between specific subtests, which reflected other research findings with regard to the high correlations between the subtests that make up the factor indexes

DISCUSSION OF FINDINGS

Theses findings demonstrate that auditory and visual stimulation resulted in significant mean changes pretest to posttest in the cognitive functions of all learning-disabled participants; therefore, all null hypotheses were rejected. The results of this study, which only used 12 sessions in 6 weeks, offer promising evidence that auditory and visual stimulation technology may be a viable intervention for learning disabilities. It would also appear that AVS may be a physical phenomenon that normalizes brainwave activity and increase neuronal activation resulting in dendritic growth. These findings will perhaps have a significant impact on strengthening the cognitive weaknesses of those with learning disorders, resulting in a multitude of effects which were not addressed in this study. First, the use of this technology could be used to decrease the degree of severity in compromised cognitive abilities such as short-term memory, sequencing, information processing, and focus and attending. Not only will this affect the academic progress by improved grades and overall performance, but it will likely increase the potential for many of these children to obtain higher levels of education and academic successes. If implemented early in life, this technological intervention may also assist in reducing the risk of behavioral and psychological issues which can accompany some of these diagnoses. In addition, early social and academic successes can enhance an individual's self-esteem and self-concept, which can positively impact the quality of relationships with others. With the likely cognitive improvements and continued social and academic successes possibly awarded through the use of AVS, a child diagnosed with learning disabilities can perhaps avoid some of the psychologically crippling and negative social and career limitations that may result without such rehabilitative intervention. With further studies in the use of such simple technology, a learning-disabled child or adult may now have an opportunity to alter his or her life, resulting in increased academic, social and personal successes affecting one's overall quality of life.

Though this study investigated specific cognitive abilities using the WISC-III SCAD profile as opposed to utilizing other measures, such as verbal and processing IQ, achievement tests, behavior rating scales, and computerized tests for impulsivity, this study confirms that AVS produces significant changes in some cognitive abilities known to be weak in LD participants.

Though this study utilized newer technology and faster frequencies, the lower number of AVS sessions needed to improve cognitive abilities may further demonstrate its efficacy. The AVS sessions were administered two times weekly for a duration of 6 weeks, which may assist in better outcomes, as daily sessions may result in overstimulation of the brain. The choice of music or story soundtrack with regard to the use of AVE did not appear to be a detriment. Additionally, this researcher used higher frequencies that of other studies (14 - 40 Hz and 40 - 14 Hz). This researcher suggests that the most significant gains in specific cognitive improvements are produced by the using faster frequencies in aiding a participant to produce more neuronal stimulation. Additionally, this study used white-full spectrum LEDs with regard to the eye glasses, which provided the light stimulus. It is the belief of this researcher that partial range frequency light stimulus such as red or other monochrome colors are not as effective as full spectrum stimulus. Additionally, the light glasses in this study were inset with four LEDs per each eye. Other light stimulus glasses may have only two or three LEDs per eye. Previous studies utilized red or other types of full spectrum glasses made by various manufacturers. The intensity and quality of these light glasses may also be a variable with regard to study results.

RECOMMENDATIONS

This study investigated only six areas of weakness: visual-motor coordination, visual short-term memory, sequencing, number ability, ability to attend, and speed of information processing. Further investigation of how AVS may affect learning disabilities might include the testing on other specific areas such as reading, comprehension, abstract thinking, social maturity and judgement, writing skills (including penmanship and written expression), listening, speaking, reasoning, and spelling.

A specific weakness in this study was the population size. Though there were only 30 participants, all children did demonstrate significant improvements. Additionally, this study did not use a control group, which is partially due to time restraints and the ethical consideration of withholding medication for those who did not want to discontinue psychostimulant use. There was also a lack of equal age representation (younger group = 18, older group = 12) and gender representation (females = 12, males = 18) in the sample population. Some of the representation may be accounted for by the suggestion that more males are diagnosed with a learning or attentional disorder than are females.

Another limitation of the study was the time between pretest and posttest. Although this researcher has found no data with regard to pretest posttest time restraints with the tests chosen, future studies should have a 6-month to 1-year follow-up measurement period. A longitudinal study design that would allow for both cognitive and behavioral measures to be evaluated is also recommended, and the use of self-reported, parent, and teacher ratings may also be used. Future studies may include a pre- determined -year follow-up to discover if academic recidivism occurs in any specific cognitive ability, and to what extent. Other studies could use brain imaging technology to measure areas of brain activation and particular changes in brain neurophysiology.

CONCLUSION

This study suggests that the use of AVS challenges and stimulates the brain to change in many ways that may not yet be understood. This researcher wrote the software protocol based on 12 years of previous experimentation with such technology. Though other AVS devices are available for use, the specific sequence of the tones and frequencies with regard to the light and sound stimulus has not been replicated in any other devices. However, the simplicity of the program use and the low cost of the equipment may allow for a relatively safe, quick, treatment intervention for learning disabilities to be available to children who not only need it, but to those who would otherwise not receive such intervention due to socioeconomic level and availability of mental and/or health coverage. Larger studies could lead to an intervention that is easily assessable by trained and licensed professionals, and more importantly, that is a safe, immediate, effective, non drug rehabilitative intervention for learning disabilities and other neurophysiological disorders. This technology has the potential to greatly enhance the quality of life for the learning-disabled individual who would be at risk for social, psychological, and a multitude of personal disappointments and life-long failures without such a treatment intervention.