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Video Games: Enhancing Attention with NASA-Developed Neurofeedback Technology

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Video Games: Enhancing Attention with NASA-Developed Neurofeedback Technology

NCTI *Technology In the Works Project*

Final Report

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TABLE OF CONTENTS

A. INTRODUCTION

Neurofeedback

Over the past several decades, biofeedback technology has been applied to the improvement of physiologic and brain functioning. EEG biofeedback or neurofeedback has been used in clinical settings with substance abusers (Scott, Kaiser, Othmer, & Sideroff, 1995; Trudeau, 2000), individuals with mental health diagnoses such as phobias (Hirshberg, Chiu, & Frazier, 2005), and individuals with attention deficit disorder (ADD) (Gruzelier & Egner, 2005; Linden, Habib, & Radojevic, 1996; Monastra, et al., 2005). The use of neurofeedback as a treatment for attention deficits dates back to the 1970s (Lubar & Shouse, 1976). During the past ten years, numerous clinical studies have documented the effectiveness of neurofeedback in reducing the core symptoms of ADD (Monastra, 2003) and as a replacement for stimulant medication. During the same period, improved neuroimaging techniques (fMRI or functional magnetic resonance imagery, SPECT or single proton enhanced computer tomography, and qEEG or quantitative neuronal brain mapping) have been useful in identifying activity levels of specific brain areas for various neurological conditions, including ADD.

Neurofeedback, sometimes called "neuronal function enhancement (NFE) training" or "self-regulation training," has been used with under-performing students who demonstrated a 6-point increase in IQ and 28% reduction in school dropout after training (Carter & Russell, 1993). NFE techniques were also used in simulation training of astronauts to increase their attention at the control panels. Alan Pope, a behavioral scientist at NASA Langley Research Center in Hampton, Virginia, and Eastern Virginia Medical School applied the technology to help clients with ADD stay focused by rewarding an attentive state of mind.

While NFE has been incorporated into the clinician's repertoire for individuals with attention deficits, an application of the technology that is engaging and easily accessed by adolescents has been missing until now.

SmartBrain Technologies PlayStation System

Recently CyberLearning Technology LLC, utilizing the NASA technology, developed equipment aimed at the adolescent population. Our intent has been to substitute the classical neurofeedback systems with technology that has the capacity to engage the interest of youth for the full duration of 30 half-hour sessions. We applied NFE techniques so that efficient brain functioning could keep a video game running. The technology, SmartBrain Technologies PlayStation System, appears to have high motivational impact among young users and it can be used at home. The SmartBrain Technologies PlayStation System, also called the SmartBrain Home System, is pictured here. The visor with the attached electrodes is also shown.

The technology acquires a real-time brain activity signal and transmits

the signal to a receiver wired into a Sony PlayStation game controller. The SmartBox NFE device is programmed for increasing the ratio of BETA brainwaves (used during focused, analytical processing mental states) to THETA and ALPHA brainwaves (used during daydreaming, tuned out, drowsy mental state). The signal output of these brainwaves provides three forms of feedback (visual, auditory and tactile) that correspond to changes in brain activity. For example, when the brain is outside the range of focus, the digital buttons on the game controller will work less efficiently. In a race car game, brain activity is measured through the Smart Box (the EEG Neurofeedback acquisition device) and a signal is sent to the accelerator button on the programmed game controller that reflects changes in the ratio of BETA/ALPHA + THETA brainwaves. If the ratio is moving in a positive direction (increased attention and processing) the accelerator button is more efficient and the car will attain top speed. If the ratio is moving in a negative direction (more daydreaming and slower processing) the accelerator button becomes less efficient and there will a proportional decrease in speed. Other forms of feedback include auditory output of the desired brain states through a speaker system and tactile feedback to the vibrator motor in the game controller. Since the goal of the game is to advance and win the race, the player is motivated to produce a brain wave state that is reflective of improved processing and attention. A protocol of thirty 30-minute sessions using the technology has been shown to increase an individual's attention.

Our technology has the potential to replace traditional neurofeedback training during which the client sits in a passive state and is provided visual and auditory feedback. Older feedback may be a bar or trend graph or even a "Go-No-Go" type animation like a Pac Man maze. The SmartBrain Technology replaces this passive state of training with the active engagement and training of the sensory-motor system. As such, it has the potential to revolutionize the accessibility and enjoyment of NFE for a wide range of audiences, including adolescents with attentional problems, the overall student population, and adults.

B. PROJECT GOAL

The goal of this project was to demonstrate the effectiveness of NFE within a home setting using the specially programmed video game controller of the SmartBrain Home System to improve the concentration and attention of adolescents identified with attentional problems.

Specific Aims include:

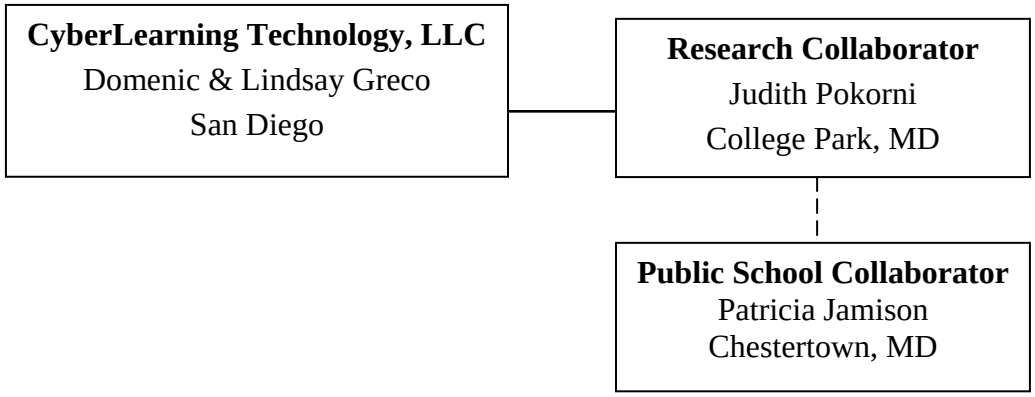
- to increase the ratio of BETA/ALPHA + THETA brainwaves
- to demonstrate improved attention in the subject's daily performance
- to improve reading concentration

C. PROJECT MANAGEMENT

The organizational chart displays the three collaborators: CyberLearning Technology, LLC, the Research Collaborator, and the Public School Collaborator. Cyber Learning Technology, LLC, provided the technology, conducted the initial and mid-intervention home visits, provided oversight of the intervention sessions and the use of the technology, and collected and analyzed the electronic session data. The Research Collaborator prepared and submitted protocols to the IRB for approval, consented the families, contacted the families to provide information on the study, scheduled and conducted the two assessments sessions, and analyzed the assessment

data from the sessions. The Public School Collaborator gathered information on potential student participants, randomized the students to intervention and comparison groups (in the presence of the Research Collaborator), and made the initial phone contact to briefly explain the project and request families' permission to speak to the Research Collaborator for further information on the project.

Figure 1 Project Collaborators



D. PROJECT PROCEDURES

Study Participants

Twelve middle school students, ranging from 12 to 17 years of age, were recruited through the Department of Special Education in the Kent County Maryland Public School district. Criteria for recruitment included:

- attended a middle school (grades 5-8) in School Year 2006-2007 and
- received medication at school for attentional problems.

Twelve students were identified as meeting the criteria. Students were randomly assigned to either an intervention or comparison group.

Recruitment

In the first phase of recruitment, the district's Director of Special Education contacted the six parents of potential intervention participants, briefly described the study and secured their agreement to be contacted by the study researcher. The families were contacted by the research and all six families agreed to participate in the study and appointments were scheduled to consent the families and begin data collection.

In the second phase of recruitment, the district's Director of Special Education contacted the 6 parents of potential comparison participants, briefly described that their participation in the study would consist of the pre and post test sessions only. She attempted once again to secure agreement to be contacted by the study researcher. Of the six potential randomly selected comparison families, only four families agreed to participate as a member of the comparison group.

In order to recruit two additional comparison group participants, the Director of Special Education began contacting students from a second middle school in the district to introduce them to the project and request permission to refer their names for follow up to the project researcher. The Director attempted to enroll from a pool of six children from the second middle school who met the criteria for participation. Of the six families: two had phones that were disconnected; one child was on vacation for the remainder of the summer; one mother was too ill to bring her child for testing; one had five children and indicated she couldn't bring all of them to the testing site; and one indicated interest but was not reached by the researcher after multiple attempts. As a result, no additional children were recruited from the second middle school and the comparison group consisted of the four families whose children attended the same middle school as those in the intervention group.

Project Components

The study included the following components:

- initial assessment session (conducted by the project researcher)
- equipment setup and demonstration home visit (conducted by the technology developers)
- neurofeedback training sessions (conducted at home by the families)
- final assessment session (conducted by the project researcher)

The comparison group participated in the two assessment sessions only.

Initial Assessment Session

The initial assessment sessions were conducted in a conference room of the local middle school. The first ten minutes of the initial assessment session was devoted to the consenting process during which the purpose and procedures of the study were described and the technology shown. Upon agreeing to participate, the parent signed the consent form and the student signed an assent form.

Once the consenting was completed, the parent was given a brief demographic/contact form and the Conners' Parent Rating Scale and escorted to another area of the school to complete the forms and wait for the student to finish the session. At the same time, the student complete the assessment battery which consisted of the Conners' Continuous Performance Test, Beery Visual Motor Intervention Test, two subtests of the Woodcock Language Proficiency Battery, and a handwriting sample. (See Measures section below.)

While the parent completed the forms, the study researcher and the students remained in the conference room and completed the measures indicated in Table 1.

Once the student assessments were administered, the child was given $20 for participating in the initial assessment session.

The initial assessment session was the same for the comparison students except no technology was shown and the parent and child were told that their only involvement in the project would be to participate in the two assessment sessions. Once the assessments were collected, the child was also given $20 for participating.

Equipment Setup and Demonstration

Once the six intervention families completed the assessment sessions, the CyberLearning Technology developers contacted the families and scheduled a home visit of approximately 90 minutes. During the home visit, the developers:

- explained the purpose of the neurofeedback training sessions
- demonstrated and setup the equipment, including the lightweight visor, 3 water-saturated sensors a game controller, and Smartbox wireless recorder.
- monitored the first 30 minute session during which the student played the video game, Grand Tursimo, using the specially programmed game controller and the receiver.
- demonstrated the process for uploading the session record and sending it via email to Cyberlearning Technology, Inc.

Before the developers left the home, the parents were given a log to complete at each session. Contact numbers were given for families in the event they had questions or problems regarding the use of the technology.

Neurofeedback Training Sessions

The neurofeedback sessions were conducted for 30 minutes five times a week under the supervision of the parent. At the end of every 10 sessions, the data were transmitted electronically over the Internet to the developers in California. Upon receipt of data for the 10 sessions, a check for $10 was sent to the parent as the child's incentive.

Once all 6 families had completed half of the sessions (20 sessions) a mid-intervention home visit was scheduled. The developers again traveled to the homes to address any problems, answer questions, and review the purpose of the training sessions. These visits lasted from 20 to 45 minutes.

The parents supervised their child during the training sessions by assisting with the positioning of the visor and sensors and checking to be sure the Smartbox was working correctly. Parents also transferred the data from the SmartBox to a computer and transmitted the session data to CyberLearning Technology at the end of each 10 sessions.

Final Assessment Session

The final assessment session was scheduled once all training sessions were completed. Since these sessions were held after the fall school schedule had begun, they were scheduled for Saturdays in a quiet meeting room at the local library. In addition to the assessments that were conducted during the initial session, parents and children were asked to complete a feedback form regarding their experience with the technology. All intervention and comparison students were given $20 for participating in the assessments. Intervention students were given an additional $20 for participating in the feedback regarding their experience using the technology.

Project Measures

Outcome Measures

Pre and post tests of measures (Table 1) were conducted during the initial and final assessment sessions for all intervention and comparison students. Collection of these measures took

approximately 45 minutes. Both intervention and control students were tested, with the exception that only the intervention group received the concentration measure which was recorded during the neurofeedback training sessions.

Table 1—Outcome Measures

Dependent Variables	Measures	Person
Attention	Conners' CPT II Continuous Performance Test II	Intervention & comparison students
Attention	Conners' Parent Rating Scale	Intervention & comparison parents
Reading Comprehension	Woodcock Language Proficiency Battery-Revised: Passage comprehension & Reading vocabulary subtests	Intervention & comparison students
Visual Motor Integration	Beery VMI	Intervention & comparison students
Concentration	BETA/ALPHA+THETA ratio from beginning to end of intervention	Intervention students

The Beta/Alpha+Theta ratios were recorded continuously during the training sessions and submitted to CyberLearning Technology every 10 sessions. This measure was used with the intervention group only.

The Conners' CPT II-Continuous Performance Test was used as one measure to assess attention. This brief, computer-based test takes 15 minutes and provides scores (errors of omission, errors of commission, response time, variability of response time) to compare intervention and nonintervention outcomes. This continuous performance test (CPT) is computer administered and scored which, compared to parent and teacher report, includes less human bias in administration and scoring.

The Conners' Parent Rating Scale-Revised Long Form was used to measure the parents' perception of their child's behaviors related to various aspects of attention. Subscales for this measure include: (a) oppositional, (b) cognitive problems/inattention, (c) hyperactivity, (d) anxious-shy, (e) perfectionism, (f) social problems, (g) psychosomatic, (h) Conners' ADHD index; (i) restlessness; and (j) emotional Lability.

Two reading subtests of the Woodcock-Johnson Tests of Achievement were used to assess reading comprehension, which is shown to be impacted by concentration. The subjects completed the Passage Comprehension and Reading Vocabulary subtests.

Input Regarding Technology

In order to further probe the usefulness of this new application, a feedback form was completed by the intervention parents and the students were asked questions regarding their experience with the technology. This information was gathered at the end of the final assessment session. The evaluation of the technology was done by the intervention group only. Questions included ease of use, problems encountered, etc.

Sample

The demographics of the intervention and comparison group are given in Table 2.The initial intervention group consisted of 6 students:

Table 2 Demographics

Gender	Grade School Year 2006-2007	Age at Pretest (Years, Months)	Participation Status
Intervention Group			
1. Male--201	7	12 - 8	Completed
2. Male--202	8	14 - 2	Dropped Out
3. Male--203	7	13 - 5	Completed
4. Male--204	7	13 - 1	Completed
5. Male--205	6	12 - 9	Dropped Out
6. Male--206	7	14 - 0	Completed
Comparison Group			
1. Male--301	8	14 -7	Completed
2. Female—302	8	14 - 2	Completed
3. Male--303	5	11- 2	Dropped Out
4. Female--304	5	10 - 7	Completed

Analysis of quantitative data will be performed to address the following research question: In comparison to the nonintervention group, did the neurofeedback intervention group demonstrate greater increases in attention, executive functions, and reading skills.

Separate two (group) X 2 (time of testing: pretest, posttest) ANOVAs will be conducted to assess the effects of NFE on the following dependent variables: attention, executive cognitive functions, and reading speed. Since the dosage (number of minutes) of NFE may vary somewhat for intervention participants, we will evaluate whether dosage is related to outcome scores for the intervention group.

Using the SmartBrain Technology logs, the pre- and post Theta/Beta ratios will be analyzed over time for each intervention participant.

Finally, we will analyze the information received during the focus groups to extract salient information regarding useability and motivational impact of the

E. RESULTS

The results are reported here in two sections. The first section compares the two groups (intervention and comparison) on the academic and attentional measures. The second section

briefly describes the outcomes of the neurofeedback data collected during the 40 sessions for the intervention group only.

Outcome Measures—Comparison of Intervention and Comparison Participants

Because of the small sample size (4 intervention and 3 comparison), statistical tests were not used. Tables 1 and 2 display pre and post tests standard scores for passage comprehension and reading vocabulary. A standard score of 100 is the median or 50 percentile, meaning that half of the population is above and half below that score. A standard score of 89 is equivalent to approximately the 24th percentile. Increases in post-test scores occurred for members of both the intervention and comparison groups. It should be noted that all seven students scored at or above a standard score of 90, indicating achievement within the normal range. However, on the reading vocabulary test, a number of students scored at or below a standard score of 85. Tables 1-6 display pre and post-tests scores for the four intervention students (202, 203, 204, 206) and the three comparison students (301, 302, 304).

Tables 1 and 2 display the two reading subscale results, passage comprehension and reading vocabulary.

Table 1 Passage Comprehension Pre and Post Standard Scores

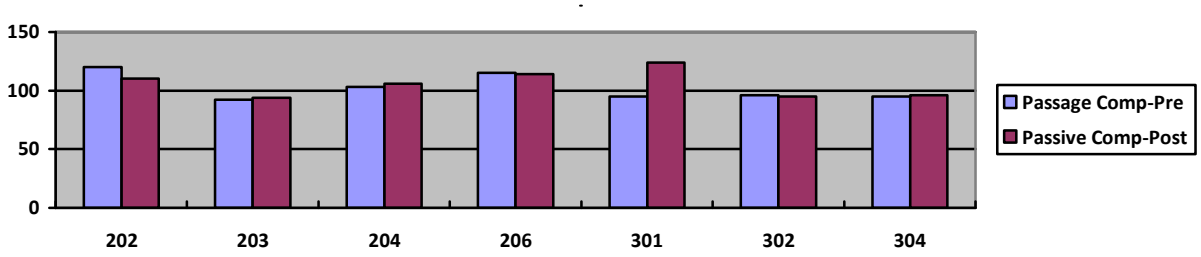


Table 2 Reading Vocabulary Pre and Post Standard Scores

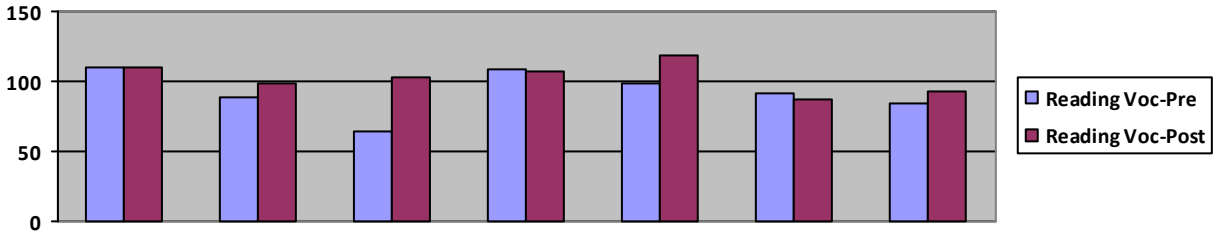


Table 3 displays the pre and post tests scores as percentiles for the quality of the handwriting sample. Handwriting samples are scored from 10 points (illegible) to 100 points (perfectly formed and artistic). For the four intervention students, two scored the same in handwriting and two increased dramatically. The three comparison students either scored the same (two) or decreased in legibility (1). Regarding the quality of the writing sample, the results indicate that two of the four intervention students had very poor handwriting (30% or less) and two had very legible handwriting.

Table 3 Handwriting Pre and Post Percentile Scores

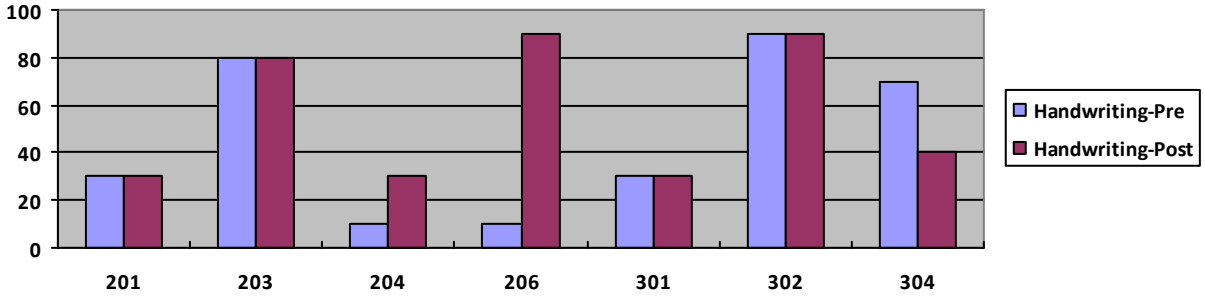


Table 4 displays the visual motor integration standard scores for both groups. Interestingly, all four integration students in the intervention group declined from pre to post tests while the three comparison group students each increased at post test.

Table 4 Visual Motor Integration Pre and Post Test

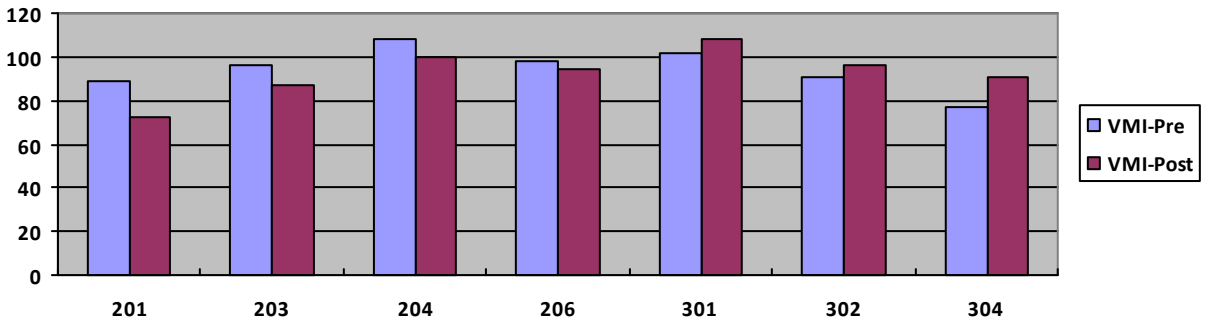


Table 5 displays the number of Conners' Parent Rating Scale-Revised Long Form subscales on which parents rated their child lower at post test than pretest. A lower rating on the 14 scales indicates less behaviors suggestion attentional or other related behavioral problems. The number of subscales that rated lower (less problematic) for the intervention students ranged from 9 to 14 while the comparison group had 7, 4, and 13 scales rated lower by their parents.

Table 5 Conners' Parent Rating Scale Subscales

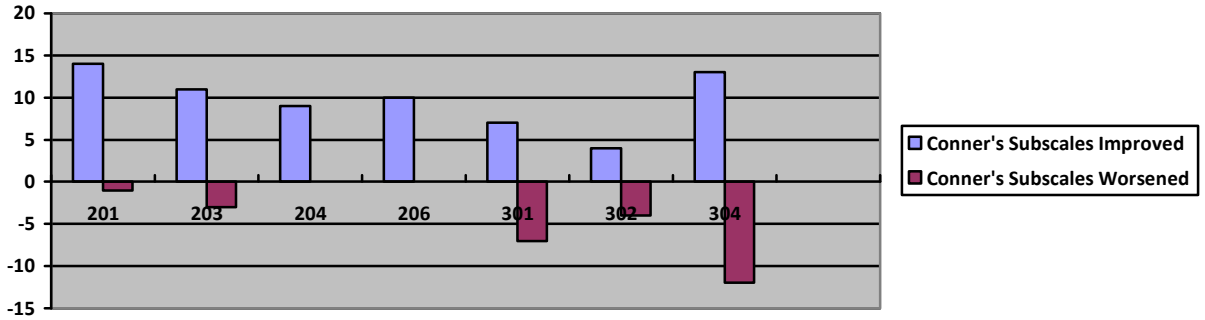
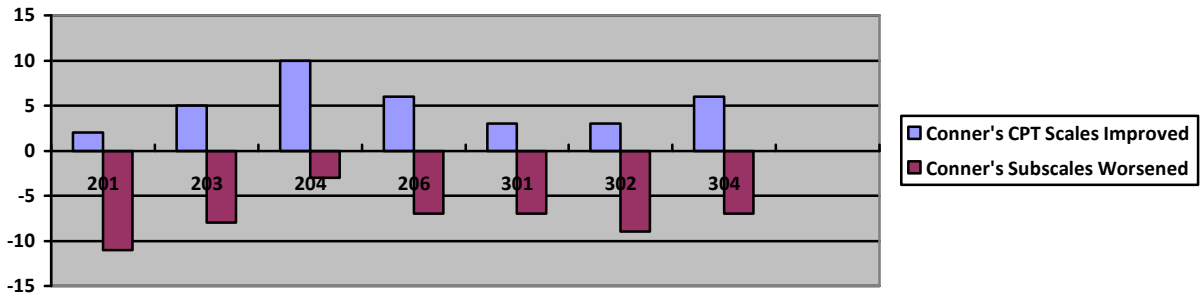


Table 6 Conners' Continuous Performance Test



Outcome Measures—Neurofeedback Data

Data were recorded continuously during each 30-minute neurofeedback session. The data indicated the ratio of BETA brainwaves (used during focused, analytical processing mental states) to THETA and ALPHA brainwaves (used during daydreaming, tuned out, drowsy mental state). The intervention is aimed at increasing the ratio indicating increased focus and attention. The data indicate that only one intervention participant (No. 206) demonstrated an increased ratio of BETA to THETA and ALPHA brainwaves; two demonstrated worsened ratios; and one demonstrated no change. Table 7 indicates the results of the neurofeedback data and includes indication of the status of the medication participants were prescribed for their attentional problems.

Table 7 EEG Data

Participant No.	EEG Results	Medication Status
201	Ratio- Worsened	No Med Change
203	Ratio- No Change	No Med Change
204	Ratio- Worsened	Back on Meds for Post
206	Ratio- Improved	Back on Meds for Post

Summary of Results

Table 7 indicates a comparison of results for each student on the three attentional measures.

Table 7 Interpretation of Results on Attentional Measures

	Conners' Parent Rating Scale	Conners' Continuous Performance Test	EEG Data
Intervention Group			
201	Improved	Worsened	Worsened
203	Improved	Worsened	No Change

	Conners' Parent Rating Scale	Conners' Continuous Performance Test	EEG Data
204	Improved	Improved	Worsened
206	Improved	Worsened	Improved
Comparison Group			
301	Worsened	Worsened	
302	Improved	Worsened	
304	Worsened	Worsened	

F. DISCUSSION

This study was designed to pilot the use of a home-based neurofeedback intervention. As such, it represents the first attempt to bring neurofeedback from the clinic to the home and without ongoing oversight of a clinician. Outcomes on both attentional and academic measures are difficult to determine for a number of reasons, including:

- the small size of the groups;
- the pre-testing was executed during the summer and post testing was collected three months into the school year when challenges are more likely to be noted;
- a number of the participants transitioned from middle to high school, a transition that is known to be difficult for some students, particularly those struggling with attentional and/or learning difficulties; and
- the medication regimes for a number of participants were interrupted during the summer and resumed before the intervention sessions were completed.

Contributions to the Field

The pilot does, however, contribute to advancing the field of promising interventions for students with attentional difficulties by demonstrating that:

- the neurofeedback technology that can be used outside a clinical setting already exists;
- the video-based technology is engaging enough to result in compliance of adolescents over the full eight-week period;
- families can successfully oversee intervention sessions of their children with minimal oversight from professionals;
- data transmission and technical assistance regarding the use of the technology and recording and transmission of the data can be accomplished with minimal telecommunication and Internet support of the clinicians.

Areas for Further Development

Feedback from students and their families indicate the following areas for further development:

- less cumbersome equipment
- more comfortable sensors
- more consistent and reliable reception of data from the controller to the recorder

- variation in video games
- less preparation for each session

The results of this small pilot suggest that the neurofeedback technology using video games has merit in eliciting cooperation of adolescent males in need of intervention because of attentional difficulties. Its use in the home setting further expands its usability. The next generation of the technology will need to address some of the issues related to ease of use. Meanwhile, larger controlled studies are needed to substantiate the intervention's positive effects for both home and academic outcomes.

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