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Pilot Feasibility Study of Binaural Auditory Beats for Reducing Symptoms of Inattention in Children and Adolescents with Attention-Deficit/Hyperactivity Disorder

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Introduction: The purpose of this pilot study was to explore the potential for the use of binaural auditory beat stimulation to reduce the symptom of inattention in children and adolescents with attention-deficit/hyperactivity disorder.
Methods: This pilot study had a randomized, double-blind, placebo-controlled design. Twenty participants were randomly assigned to listen to either an audio program on compact disk that contained binaural auditory beats or a sham audio program that did not have binaural beats for 20 minutes, three times a week for 3 weeks. The Children's Color Trails Test, the Color Trails Test, the Test of Variables of Attention (TOVA), and the Homework Problem Checklist were used to measure changes in inattention pre- and postintervention.
Results: Repeated measures analysis of variance was used to analyze pre- and postintervention scores on the Color Trails Tests, Homework Problem Checklist, and the TOVA. The effect of time was significant on the Color Trails Test. However, there were no significant group differences on the Color Trails Test or the TOVA scores postintervention. Parents reported that the study participants had fewer homework problems postintervention.
Discussion: The results from this study indicate that binaural auditory beat stimulation did not significantly reduce the symptom of inattention in the experimental group. However, parents and adolescents stated that homework problems due to inattention improved during the 3-week study. Parents and participants stated that the modality was easy to use and helpful. Therefore, this modality should be studied over a longer time frame in a larger sample to further its effectiveness to reduce the symptom of inattention in those diagnosed with attention-deficit/hyperactivity disorder.

ATTENTION-DEFICIT/HYPERACTIVITY disorder (ADHD) is one of the most common neurobehavioral conditions diagnosed in children and adolescents. Children and adolescents affected by ADHD exhibit the following clinically impairing, core symptoms in varying degrees of severity: inattention, hyperactivity, and impulsivity (Barkley, 1998; Barkley, 2003a, 2003b; Daly, Creed, Xanthopoulos, & Brown, 2007). Because of these symptoms, individuals with ADHD are at risk of psychosocial dysfunction throughout childhood, adolescence, and for some, during their adult years (Daly et al., 2007). Although stimulant medications are commonly prescribed to treat the symptoms of ADHD, many parents are interested in alternative and complementary modalities (CAM) to avoid side effects attributed to these medications. To date, most of the CAM modalities have not undergone systematic, rigorous study to determine their effectiveness in treating

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ADHD symptoms (Atwater, 1997; Sorenson, 1999). Recently, the dangers of psychostimulants have been documented, reinforcing the need for further testing of safe and effective modalities to reduce symptoms in children and adolescents with ADHD (Nissen, 2006).

Binaural auditory beat stimulation (BABS) is a CAM modality that has some evidence to support its usefulness in reducing symptoms such as anxiety and inattention (Le Scouarnec et al., 2001; Sorenson, 1999). Therefore, the purpose of this pilot study was to examine the feasibility and effectiveness of BABS in reducing the symptoms of inattention in children and adolescents diagnosed as having ADHD.

A Review of the Literature

ADHD is the most common neurobehavioral disorder diagnosed in childhood affecting 5% to 8% of school-aged children (Sheridan, Hinshaw, & D'Esposito, 2007). The core symptoms of ADHD (hyperactive, inattentive, and/or impulsive behaviors) often result in secondary and peripheral behaviors such as inadequate social skills, strained family and peer relationships, learning problems, school failure, and low self-esteem (Barbaresi, Katysic, Colligan, Weaver, & Jacobsen, 2007; Hoza, 2006). The diagnosis of ADHD is made using criteria established by the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (American Psychiatric Association, 1994; Schonwald, 2005).

An estimated 78% of children with ADHD continue to display symptoms as teenagers. Although the symptom of hyperactivity may subside during adolescence, inattention and impulsivity often persist, which may result in higher physical injury rates (i.e., motor vehicle, bicycle, and pedestrian accidents), problems at school and at home, lower scores on standardized tests, and failure to complete high school when compared to their unaffected peers (Barbaresi et al., 2007; Barkley, Murphy, & Kwasnik, 1996; Coleman et al., 2002; Cox, Merkel, Penberthy, Kotachev, & Jamlom, 2004). In addition, adolescents with ADHD, especially those with primarily inattentive symptoms, are more likely to become dependent on cigarettes, alcohol, and illicit drugs and maintain their dependence on these substances when compared to their unaffected peers (Marshall, Molina, & Pelham, 2003; Wilens, Faraone, Biederman, & Gunawardene, 2002). Adolescents with ADHD are also more likely to be involved in violent crimes and experience teenage pregnancy when compared to those without the disorder (Sourander et al., 2006; National Institutes of Mental Health, 2004).

Older adolescents with ADHD face a number of obstacles as college students and are more likely to fail and/or drop out of school due to attentional problems, poor organizational and study habits, and inappropriate social skills (Wolf, 2001). In addition, college students with ADHD are more likely to experience depression, poor self-esteem, and substance abuse when compared to their unaffected peers (Murphy, Barkley, & Bush, 2002; Wolf, 2001).

Psychostimulants such as Adderall, Concerta, and Ritalin are effective treatment for 70% of the children and adolescents with ADHD (MTA Cooperative Group, 1999, 2004; Schonwald, 2006). However, 30% of those with ADHD do not respond to stimulant medication, which is usually attributed to the unpleasant side effects from medication that includes irritability, insomnia, nausea, and headaches (Schonwald, 2006). Some children and adolescents may also experience temporary growth suppression due to the medication, and others experience worrisome rebound behavioral symptoms once the beneficial effects from the medication subside (Schonwald, 2006). Recently, The Food and Drug Administration recommended a black box warning on stimulant medications due to the cardiovascular risks associated with these medications.

Behavioral therapies (i.e., positive reinforcement for desired behaviors, punishment for undesired behaviors, social skills training, and parent therapy) have been found to be effective in treating the peripheral symptoms of ADHD. Parent training has long been employed to modify behavioral problems in children with ADHD. This modality is useful in improving parenting skills and reducing family stress (Daly et al., 2007). However, these therapies are not helpful in alleviating the core symptoms of the disorder (Daly et al., 2007).

Classroom interventions (i.e., daily report cards, contingency management strategies, and token systems) have been more effective in controlling disruptive behaviors in the classroom than improving academic performance (Daly et al., 2007). In addition, interventions that focus on social-problem solving and behavior management skills have been useful in improving peer relationships for children with ADHD (Daly et al., 2007).

Behavioral therapies are time intensive and require treatment by a trained specialist, resulting in higher health care expenses and failure of coverage by most health insurance plans. In addition, the effectiveness of behavioral therapies to treat ADHD symptoms has been questioned by experts in the field unless they are used concurrently with psychostimulants (Wilens, Biederman, & Spencer, 2002).

Because of the side effects and potential for adverse events of psychostimulants and the difficulty of obtaining behavioral therapy, parents who are concerned about the side effects associated with stimulant medication often seek self-directed alternative and complementary medicine (CAM) for their child and/or adolescent. Parents choose a CAM therapy for various reasons, but most state they prefer not to give their child mind-altering drugs and are worried about the short- and long-term side effects associated these medications (Chan, Zhan, & Homer, 2002). In addition, parents are concerned about the habit-forming potential associated with stimulant medications (Kirby, Rutman, & Bernstein, 2002). CAM modalities that have been used by parents and adolescents to treat ADHD symptoms include herbal remedies, nutritional

supplements, hypnosis, biofeedback, massage, spinal manipulation, acupuncture, and homeopathy (Chan et al., 2002; Richardson & Montgomery, 2005). Most CAM modalities have not undergone rigorous examination and do not have documented effectiveness (Chan et al., 2002).

Binaural Auditory Beat Stimulation

Over the past two decades binaural auditory beats (BABs) at various sound frequencies have been used to treat many disorders and to induce various psychological states including pain, relaxation, meditation, and anxiety as well as to enhance vigilance and memory.

First discovered by a German experimenter in 1839, BABs were considered by many to be an insignificant variation of monaural beats, meaning beats that can be heard by one ear alone as well as by both ears (Oster, 1973). BABs are normally occurring brainstem responses to auditory stimuli that occur when two slightly different pure tones are presented, one to each ear. The superior olivary nucleus in the brainstem interprets the phase difference between the two tones, hence the binaural beat. For example, if a tone of 120 Hz is presented to the right ear and a tone of 130 Hz is presented to the left ear, the phase difference between the two tones would be 10 Hz, the binaural beat (Lane, Kasian, Owens, & Marsh, 1998).

During the 20th century, researchers using more sophisticated technology were able to draw a distinction between the two types of beats. With the development of the electroencephalogram (EEG), it became clear that certain sound frequencies were capable of inducing EEG changes. For example, binaural beats in the delta range (1–4 Hz) are associated with sleep; those in theta range, (4–8 Hz) are associated with slow brain activity, whereas those in the alpha range (8–13 Hz) are found in individuals who are awake but relaxed. Binaural beats in the beta range (16–24 Hz) occur in states of alertness and concentration (Atwater, 1997; Lane et al., 1998; Morse, 1992; Sorenson, 1999).

It has been postulated that artificially presenting BABs at different sound frequencies may affect a person's state of consciousness by entraining the frequency-following response (i.e., brain waves change when different frequencies are presented) as measured using the EEG. This belief is supported in part by preliminary findings that suggested that increased alpha production occurred when individuals listened to audio tapes containing alpha frequency BABs as documented by EEG (Foster, 1996).

In recent years, the ability of BABs to induce changes in consciousness has been studied by many researchers. For example, in one study, 15 women listened to music tapes containing BABs in the delta range five times a week for 4 weeks. Women reported feeling less anxious at the end of the 4-week study (Le Scouarnec et al., 2001). In another study, 29 college-aged students' demonstrated improvement during vigilance tasks as they listed to music tapes containing BABs in the beta range (Lane, Kasian, Owens, & Marsh, 1998). One descriptive study found that children with ADHD demonstrated an increase in attentive behaviors after listening to music tapes with BABs in the beta range. This was a small study (n = 12) and consisted of parent and child feedback (Sorenson, 1999). However, their positive responses may be explained by the results of a recent study that found that children with ADHD have an increase in theta activity and a decrease in beta activity on electroencephalography (EEG) when compared to their peers without ADHD (El-Sayed, Larsson, Persson, & Rydelius, 2002). Perhaps, listening to tapes containing BABs in the beta range did in fact increase their ability to concentrate.

To date, few rigorous, well-designed studies have been conducted to determine the effectiveness of BABs on symptom management in children and adolescents with ADHD. Given the potential side effects and adverse events related to psychostimulant medication, further testing of safe and effective modalities for ADHD is needed. Therefore, the purposes of this pilot study were to examine the feasibility of BABS and to examine the effects symptoms of inattention in a sample of children and adolescents 8 to 21 years of age as they completed homework assignments.

Methods

This study was a randomized, double-blind, placebo-controlled exploratory pilot investigation to determine the effectiveness of BABs on the symptom of inattention in children and adolescents with ADHD.

Setting and Sample

A convenience sample of 20 children and adolescents was recruited from local pediatrician's offices and local newspapers. Inclusion criteria included (a) diagnosis of ADHD, as determined by a primary care physician, psychologist, or psychiatrist; (b) ages 8 to 21; and (c) currently taking stimulant medication. Exclusion criteria included (a) mental retardation or severe learning disabilities; (b) seizure disorders that require anticonvulsant therapy; (c) a history of mania or psychosis; (d) and/or currently taking stimulant medication after 3 p.m. for those receiving short-acting medication, after 12 noon for those receiving intermediate-acting medication and after 9 a.m. for those receiving long-acting medication to decrease the effects of medication on inattentive behaviors.

Procedures

Children and adolescents (younger than 18 years) and their parents met with the investigator to learn about the study. If the parents and the child or adolescent expressed interest in participating in the study, they were asked to sign a

consent form, and children less than 18 years were asked to sign an assent form. Participants who were 18 years of age or older signed the consent form themselves. All participants were then screened to determine whether they meet the inclusion criteria. If prospective participants did not meet inclusion criteria, the reasons for their exclusion were explained to them.

Music (natural sounds) compact disks (CDs) containing BABs in the beta range were given to children and adolescents who were randomly assigned to the treatment group. Participants assigned to the placebo group were given an audio program (pink noise) CD that was identical in sound to the intervention CD but did not contain BABs. The investigator was blinded to the type of CD by the company who developed the CDs. Once the study was completed and data analyzed, a researcher at the Monroe Institute informed the investigator of CD category.

Instrumentation

Demographic Questionnaire

A demographic questionnaire was used to collect baseline information about the child/adolescent and the parents. Parents and older adolescents provided the following information: prenatal history, medical history, age, gender, age of diagnosis, treatment, and associated problems (e.g., peer and family relationships, school performance, and the presence of comorbid disorders).

Test of Variables of Attention

The Test of Variables of Attention (TOVA) is a non-language-based, computerized, continuous-performance test developed to assess attention and impulse control in people between the ages of 4 and 80. The test–retest reliability of the TOVA is as follows: (a) scores of omission ranged from 0.72 to 0.93; (b) errors of commission ranged from 0.71 to 0.96; (c) response time ranged from 0.85 to 0.99; and (d) response time variability ranged from 0.87 to 0.99 (Whiston, n.d.; Whiston, 2001). The ability of the TOVA to differentiate correctly children and adolescents with and without ADHD was found to be 80% (Whiston, 2001).

The Color Trails Tests 1 and 2

The Color Trails Tests 1 and 2 (CTT1 and CTT2) are culturally sensitive tests used to measure sustained visual attention, eye–hand coordination, and information-processing abilities in people 18 years and older (D'Elia, Satz, Uchiyama, & White, n.d.; D'Elia, Satz, Uchiyama, & White, 1996; Llorente, Williams, Satz, & D'Elia, 2003). Test–Retest reliability coefficients for CTT1 was $r = 0.644$ and for CTT2, $r = 0.787$. Temporal stability was determined by comparing the results from the timed scores with the clinical interpretation and found to be 100% for CTT1 and CTT2 (D'Elia, Satz, Uchiyama, & White, 1996). Convergent validity was determined by comparing the correlation coefficients between CTT1 and the Trail Making Test A (TMT A), $r = 0.41$, and the CTT2 and the TMT B, $r = 50$ (D'Elia, Satz, Uchiyama, & White, 1996).

The Children's Color Trails Test 1 and 2

The Children's Color Trails Test 1 and 2 (CCTT1 and CCTT2) are culturally unbiased tests used to measure neurological functioning in children between 8 and 16 years of age and are designed to assess sustained attention, eye–hand coordination, and information processing (Llorente et al., 2003). Psychological Assessment Resources, Inc., has provided preliminary data regarding the psychometric properties of the CCTT1 and CCTT2. The alternate form reliability of the test was found to be 0.85 and 0.90 after comparing the CCTT1 and CCTT2 with alternate forms K and X. Concurrent validity was determined by comparing the correlation coefficients between CCTT1 and the SCTMT A (Standard Children's Trail Making Test), $r = 0.74$, and the CCTT2 and the SCTMT B, $r = 0.67$ (Llorente et al., 2003).

Temporal stability (test–retest reliability) was determined by comparing the scores on the CCTT1 and CCTT2 on two occasions in a cohort of 63 children diagnosed with ADHD. The test–retest coefficients for the CCTT1 and CCTT2 were $r = 0.68$ and $r = 0.60$, respectively. In addition, results obtained from a sample of 200 children diagnosed as having mild neurological disorders, learning disabilities, and ADHD found that children and adolescents with ADHD had the lowest scores on the CCTT. This result is a further indication of the test's ability to detect inattentive behaviors in these children (Williams et al., 1995).

Homework Problem Checklist

The Homework Problem Checklist (HPC) was developed as a tool to help parents identify problems that their child may have regarding homework (Anesko & Levine, 1987; Anesko & O'Leary, 1983). Construct validity was found to meet or exceed standard psychometric criteria (Anesko, Schoiock, Ramirez, & Levine, 1987), and the internal consistency of the entire scale as determined using Cronbach's alpha was acceptable at .91. The HPC has successfully used to measure homework problems in children between the ages of 7 and 18 years who have behavioral disorders. In this study, the Cronbach's alpha for internal consistency was .76 for the teacher and parent ratings (Foley & Epstein, 1993).

Procedures

Approval for the study was obtained through the institutional review board for the Social and Behavioral Sciences. Parental or adolescent consent/child assent was obtained prior to beginning data collection.

Study Entry and Pretest

During the initial meeting, parents, older adolescents, and children met with the investigator for approximately 30

minutes to discuss the intervention and requirements of the study. Parents and older adolescents filled out a demographic questionnaire. The child or adolescent was given a 3-minute orientation to the TOVA prior to completing the actual test. In addition, the participants completed the CCTT (children aged 8–16 years of age) or the CTT (adolescents 16–22 years of age).

Intervention

Instructions were given to parents and the study participant about the use of the audio program on CD. Participants were instructed to listen to the CD using headphones for 20 minutes, three times a week while they completed their homework assignments. Parents of children with ages 8 to 13 completed the HPC after the child finished his or her homework assignment. Older adolescents (aged 14–21 years) completed the HPC after finishing each homework assignment.

At the conclusion of the study, children and adolescents returned to the School of Nursing for additional testing. Participants were asked to complete a second TOVA test and CTT or CCTT while listening to their assigned CD and completing both tests. The nine HPCs were collected at this time. Children and adolescents were given a $40 mall certificate for participating in this study.

Analysis

The sample was composed of 20 children and adolescents between 8 and 21 years of age. The mean age was 14.25 years (*SD* = 5.35). The racial breakdown included 14 Caucasians (70%), 4 African Americans (20%), 1 Asian (5%), and 1 Hispanic (5%). Participants were categorized by their level of education at the time of the study. Of the 20 participants, 5 were elementary school children (25%), 5 were in middle school (25%), 2 were in high school students (10%), and 8 were in college (40%). There were no significant differences between the two groups on these variables.

Group differences at baseline on the pretests (i.e., CTT, CCTT, and HPC) were not significantly different. However, the baseline omission scores from the two groups were compared using independent *t* tests, and a marginally significant difference was found between the two groups ($p = .052$). Results are shown in Table 1.

Differences in baseline and postintervention scores between the intervention and sham groups on the Color Trail Test 1-combined (CTT1-C; CTT1 and CCTT1) and the Color Trail Test 2-combined (CTT2-C; CTT2 and CCTT2) were analyzed using repeated measures analysis of variance (ANOVA) models. TOVA omission scores were analyzed using the analysis of covariance (ANCOVA) model due to significant baseline differences between the two groups.

Table 1 Tests of Group Differences at Baseline on CTTs, Omission Errors (TOVA), and the HPC

	Group Assignment				
		Sham	Intervention		
Variable	Total	CD	CD	*T* test	*p*
CTT1					
M	42.50	37.75	47.25	−0.89	.45
SD	16.18	15.52	17.61		
CTT2					
M	43.50	44.25	42.75	0.16	.88
SD	12.40	6.07	17.91		
CCTT1					
M	40.00	37.66	42.33	0.65	.53
SD	12.11	11.24	13.54		
CCTT2					
M	36.41	37.83	35.00	0.40	.70
SD	11.92	13.55	11.15		
CTT1-C					
M	41.00	37.70	44.30	1.10	.29
SD	13.52	12.26	14.55		
CTT2-C					
M	39.25	40.40	38.10	0.41	.69
SD	12.32	11.19	13.86		
Omission error (TOVA)					
M	1.06	0.94	1.17	−2.08	.05
SD	0.28	0.25	0.27		
HPC					
M	9.60	10.70	8.50	1.30	.20
SD	3.77	4.35	2.92		

Color Trail Test 1-Combined (CTT1 and CCTT1)

When testing differences in scores between the intervention group and the sham group on the CTT1-C, the between-group factor was the intervention group (CD vs. the sham CD) and the within-group factor was time. Results are shown in Table 2. The within-subjects factor of time was significant ($p = .04$), indicating an improvement in inattentive symptoms over time regardless of group assignment. The interaction of Time × Group was not significant ($p = .74$). These findings indicate that the participants in the intervention group did not experience a larger reduction in inattentive symptoms over time compared to the sham group.

Color Trail Test 2-Combined (CTT2 and CCTT2)

When testing the differences in scores between the intervention group and the sham group on the CTT2-C, the between-group factor was the intervention (CD vs. the sham CD) and the within-group factor was time. The within-subjects factor of time was significant ($p = .02$), indicating an improvement in inattentive symptoms over time regardless of group assignment. Results are shown in Table 3. These findings indicate that the participants in the intervention group did not experience a larger reduction in inattentive

Table 2 Differences Between Groups on the CTT1-C at Baseline and Postintervention

CTT1-C	*SS*	*Df*	*MS*	*F*	*p*	ES	Power
Between subjects							
Group	324.90	1	324.90	1.28	.27	0.07	0.19
Error	4,571.10	18	253.95				
Within subjects							
Time	360.00	1	360.00	4.92	.04	0.22	0.56
Time × Group	8.10	1	8.10	0.11	.74	0.01	0.06
Error	1,315.90	18	73.10				

Note. ES = effect size.

symptoms over time when compared to the sham group. The interaction of Time × Group was not significant ($p = .99$). In addition, there were no significant group differences in scores on the CTT2-C ($p = .64$).

TOVA Omission Errors

Because of the marginally significantly differences between the sham and intervention groups at baseline, the scores on the TOVA omission errors were analyzed using ANCOVA. Results are shown in Table 4. The Levine's Test of Equality of Error Variances was nonsignificant ($p = .75$). Preintervention omission error was a nonsignificant covariate (0.09). The between-subject factor of group assignment was nonsignificant ($p = .28$); however, the power of this measure to detect group differences was low (19%).

Homework Problem Checklist

Differences in scores between the intervention group and the sham group on the HPC were analyzed using repeated measures ANOVA. The between-group factor was the intervention CD versus the sham CD and the within-group factor was time. The Greenhouse-Geisser epsilon correction was used to analyze the scores on this measure.

Scores on the HPC significantly decreased over the 3-week intervention regardless of group assignment ($p < .01$). However, there were no significant differences between the two groups ($p = .19$) or in the interaction of Time × Group ($p = .82$). Results are shown in Table 5.

A secondary aim of this study was to test the feasibility of conducting a study using BABS as a complementary modality to treat the symptom of inattention in children and adolescents with ADHD by determining (a) the number of children and adolescents who met the established sampling criteria and were eligible and agreed to participate in this study; (b) the number of participants who dropped out of this study; and (c) the reported level of adherence to the study protocol.

All of the children whose parents responded to the study advertisements met the inclusion/exclusion criteria and agreed to participate in the study. This was true for the older adolescents as well. Although this accrual response is somewhat unusual, it may be due to the detailed information that was provided in the various brochures, flyers, and newspaper advertisements. All participants completed the CTT and the TOVA pre- and postintervention. The HPCs were returned by all participants or their parents during the final meeting.

Table 3 Differences Between Groups on the CTT2-C at Baseline and Postintervention

CTT2-C	*SS*	*Df*	*MS*	*F*	*p*	ES	Power
Between subjects							
Group	55.22	1	55.22	0.23	0.64	0.01	0.07
Error	4,288.7	18	238.3				
Within subjects							
Time	600.63	1	600.63	6.78	0.02	0.27	0.69
Time × Group	0.03	1	0.03	0.00	0.99	0.00	0.05
Error	1,593.85	18	88.55				

Note. ES = effect size.

Table 4 Differences Between Groups on the TOVA Omission Error at Baseline and Postintervention Using ANCOVA

Omission Error	*SS*	*Df*	MS	*F*	*p*	ES	Power
Between subjects							
Omission errors 1	0.38	1	0.38	3.21	.09	0.16	0.39
Group	0.15	1	0.15	1.27	.28	0.07	0.19
Error	2.03	20	0.12				

Note. ES = effect size.

Discussion

BABS as a modality to treat the ADHD symptom of inattention has not been well studied. For this reason, this study was designed to determine if this complementary modality was effective in reducing inattention in children

Table 5 Differences Between Groups in the HPCs Weeks 1 Through Week 9

HPC	*SS*	*Df*	*MS*	*F*	*p*	ES	Power
Between subjects							
Group	211.25	1	211.25	1.79	.19	0.09	0.25
Error	2,124.40	18	118.00				
Within subjects							
Time	327.61	3.31	98.99	8.79	<.01 [a]	0.33	0.99
Time × Group	12.50	3.31	3.87	0.34	.82 [a]	0.02	0.12
Error	670.33	144	4.65				

Note. ES = effect size.
[a] Greenhouse-Geisser epsilon correction.

and adolescents with ADHD. Unlike other modalities for ADHD, BABS is inexpensive, easy to use, and does not appear to be associated with any side effects.

In this pilot, between-group differences were not observed. Scores on the CTT1 and CTT2 and the CCTT1 and CCTT2 decreased over time in both groups, possibly indicating an improvement in inattentive symptoms over time. However, improvement in CTT scores over time has been noted by others who have used the CTT to assess changes in attention (Voight et al., 2001). The improvement may be related to familiarity with the test instead of improvement in the target symptom.

There were no statistically significant group differences in TOVA omission scores over time (baseline to post-intervention), indicating that participants in the intervention group did not was not cited in the original manuscript and was thus inserted here. Please check if this is an appropriate location.was cited here but was not included in the reference list. Please check.experience a reduction in inattentive symptoms over time compared to the sham group. However, the power of the measure was low, which may be attributed to the small sample size. Similarly, scores on the HPC significantly decreased over the 3-week intervention in both the intervention and sham groups. However, the intervention group did not have significantly more reductions than the sham group. These findings may be attributed to the Hawthorne effect because the participants were aware that they were being observed while completing their homework assignments.

Although the use of BABS did not significantly reduce the symptom of inattention in this study sample, most parents and adolescents stated that listening to the CDs was helpful in reducing inattention while completing homework assignments. One parent of a 9-year-old stated that her daughter's grades on homework assignments improved during the 3-week study and asked to borrow the CD until the study ended. Most participants or their parents also requested a copy of the CD. Parents and adolescents in both groups reported less inattentive symptoms while completing homework assignments, which may have been due to the soothing background music provided by the CD and not to the embedded BABs.

Study Limitations

Because of the small sample size, our results did not determine the effectiveness of BABS in reducing the symptom of inattention. The small sample size reduced the power of the measurements to detect group differences in inattentive symptoms. Selection bias was a limitation in this study because the sample was composed of volunteers who were recruited through flyers, brochures, and newspaper advertisements. Younger children had more difficulty than high-school-age and college-age participants completing the 21-minute TOVA test because of restlessness. The length of time to complete the test, plus the excitement associated with the anticipation of receiving the gift certificate, resulted in a few of the children impulsively clicking the microswitch at the wrong time rushing to complete the test quickly. This behavior resulted in higher than expected negative scores on the TOVA omission errors. However, these behaviors are characteristic of children with ADHD.

The HPC was a subjective measurement, and it may have been difficult for parents and adolescents to remain objective as they completed the checklist. In addition, adolescents monitored their own homework behaviors; therefore, the time when homework was completed may have varied in this group of participants. Scores on the HPC significantly improved for participants in both groups. This improvement in scores may reflect improved homework behaviors, but it also may be due to social desirability, an expected source of measurement error when self-report measures are used in clinical research studies (Polit & Hungler, 1991).

Directions for Future Research

The purpose of this exploratory study was to examine the effectiveness of BABS in reducing the symptom of inattention in children and adolescents because this modality has not undergone rigorous study in the past. The pilot study confirmed the feasibility of using BABS, but the sample was too small to examine group differences. There were no side effects or adverse events noted by participants or parents. In fact, many of the parents and adolescents believed that the CDs were helpful in reducing homework problems due to the symptom of inattention. Because BABS is a safe, noninvasive, and potentially useful modality for reducing the homework problems associated with ADHD, this modality should be investigated further using a larger sample of children and adolescents. Study of BABS in college students using different objective instruments to detect changes in inattentive behaviors may be indicated. The rationale for studying older adolescents and college students is that they may be more motivated to use the modality and they may be less impulsive when completing the study instruments when compared to younger children. Finally, future studies should follow participants for an extended period of time to determine the effectiveness of this therapy over time.

In summary, because there are limited studies using BABS as an intervention, attention in future studies should be given to (a) how the CDs embedded with the BABs are used including length of time and frequency; (b) the sample selected to test the effects of the BABs; (c) the measurement tools chosen to evaluate the effects; and (d) addressing the inconsistencies in the limited published studies. The goal of addressing these points in future studies would be to bring consistency to aspects of the research testing the effects of BABS.

Conclusion

Complementary and alternative modalities to treat children with ADHD have increased substantially over the last decade. Parents continue to seek complementary and alternative modalities because they are concerned about the side effects associated with stimulant medications. Most of the complementary modalities have not undergone rigorous study to determine the effectiveness of these to reduce ADHD symptoms.

The present study investigated the effectiveness of BABS on the symptom of inattention in children and adolescents. Although the results from this investigation were not statistically significant, it was important to assess this modality using a rigorous study approach to determine its effectiveness. In addition, parents and participants believed that listening to the CDs were helpful in reducing inattentive behaviors while completing homework assignments. However, it is difficult to determine if this reduction was due to the CDs or the CDs that contained the BABs.

The results from this study may be helpful in providing parents, adolescents, and children with information regarding this modality and its effects on inattention. Future research may reveal that BABS is an effective modality to treat inattention for those with ADHD as they complete homework assignments.

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