Global Journal of Intellectual & Developmental Disabilities
ISSN: 2575-8586

Research Article
Volume 13 Issue 1 - December 2023
DOI: 10.19080/GJIDD.2023.13.555852

Glob J Intellect Dev Disabil
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The Effects of Auditory Stimulation on Mathematical Performance for Girls with Attention Deficit Hyperactivity Disorder

Megan E Maloy Shepley and Scott Bellini*

Indiana University, United States

Submission: November 22, 2023; **Published:** December 07, 2023

***Corresponding author:** : Scott Bellini, Indiana University, 201 North Rose Avenue, Bloomington, Indiana, United States, Email: sbellini@indiana.edu

Abstract

Attention Deficit Hyperactivity Disorder (ADHD) is a neuro-behavioral disorder that can affect all aspects of a child's life, especially school performance. Parents of children with ADHD describe how their children prefer the use of external stimulation, such as music or the sound of a television while completing homework tasks but are often concerned that it will serve as a source of distraction. On the contrary, previous research has demonstrated that external stimulation may have a positive impact on academic performance for these children. The purpose of the current study is to examine the differential effects of auditory stimulation on the mathematical performance of three girls with ADHD. A single case, alternating treatment design was used across participants in a classroom setting. All three participants showed an increase in mathematical performance with the use of classical music, while only one participant showed a clear increase in performance with the use of white noise. None of the participants demonstrated a clear increase in math performance with the use of noise reduction headphones or silence.

Keywords: Attention Deficit hyperactivity disorder; Neurobehavioral disorder; Diagnosis; Optimal stimulation theory; Rainstorm; Music intervention

Abbreviations: ADHD: Attention Deficit Hyperactivity Disorder; MBA: Moderate Brain Arousal; M-COMP: Mathematics Computation; IOA: Inter-Observer Agreement; CSA: Canadian Standards Association; CBM: Curriculum-Based Measurement; NIDCD: National Institute of Deafness and Other Communication Disorders

Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a neurobehavioral disorder characterized by over activity and impulsiveness beyond what is considered normal development [1]. ADHD affects three to ten percent of school-aged children in the United States with boys being three to five times more likely to have ADHD than girls [2,3]. Four million school-aged children in the U.S. are affected with the disorder, and it is estimated that every teacher has at least one child with ADHD in his or her classroom. The symptoms of ADHD affect all aspects of an individual's life. Early recognition, assessment, diagnosis, and treatment of ADHD are important to minimize the impact of the disorder on the individual's social and emotional development, including school performance, interactions, and self-esteem. The classroom setting presents unique challenges to students with ADHD due to their inherent attentional difficulties and wide range of potentially distracting environmental stimuli. Many of the symptoms associated with ADHD impact a child's level of engagement during academic tasks, which substantially hinders their academic performance. Students with ADHD are at greater risk of academic problems including poor grades, grade retention, and school completion [4,5]. Teachers and parents repeatedly report that children with ADHD underachieve in academics compared to their peers [3,4]. Though students with ADHD possess the requisite academic skills necessary to be successful in school, their attentional difficulties and hyperactivity often hinder academic performance [3]. Students with ADHD tend to demonstrate high levels of activity when they encounter a task or situation of low arousal or stimulation. In a school setting, children must selectively attend to one task or activity as opposed to another, and then sustain their attention long enough to complete the task. However, under-selective and under-sustained attention is a hallmark characteristic of ADHD [4]. Therefore, students with

ADHD often require interventions that facilitate and promote their attention to the task at hand. One such intervention is the use of external stimulation.

Optimal stimulation theory

Nearly 50 years ago, Zentall [6] demonstrated that increasing arousal or stimulation could increase task performance for children with ADHD. Zentall 's Optimal Stimulation Theory suggests that children with ADHD demonstrate high levels of hyperactivity when they encounter a task or situation that evokes low arousal or involves low stimulation. In addition, when levels of stimulation are low, children with ADHD typically display hyperactive behavior which leads to low task performance [7]. The hyperactive behavior, thus, becomes a compensatory response to low levels of stimulation as the child seeks external stimulation to help them focus [7]. According to the Optimal Stimulation Theory, the distractibility of those with ADHD is a functional attempt to control their low levels of stimulation by seeking increased levels of stimulation. Due to this need for increased stimulation in children with ADHD, it is proposed that performance levels of these children will increase, rather than decrease, with increased external stimulation in their environment compared to a quiet environment. Therefore, the Optimal Stimulation Theory posits that children with ADHD need external stimulation to help them maintain and increase their performance level on academic tasks. Music may serve as a good source of external stimulation for children with ADHD, as music is desirable and familiar to children [6,8]. Researchers have proposed that listening to music affects cognitive performance, and such effects can be attributed to changes in an individual's arousal or mood [9]. When children with ADHD listen to music, the increased external stimulation could increase both arousal and attention. This ability to increase attention can have a positive impact as children with ADHD complete academic tasks.

Auditory Stimulation as a Source of External Stimulation

Children with ADHD often express a preference for the presence of external stimulation, such as the television or stereo while completing homework tasks, however, parents express concern that the external stimulations may be distracting and hinder their academic performance [10]. However, previous research suggests that background noise can positively impact performance in children with ADHD [11]. According to the Moderate Brain Arousal model (MBA) for ADHD, environmental noise is introduced into the neural system of individuals through the perceptual system, which allows for reduced neural background activity and the hypo-functional dopamine system in children with ADHD [11]. The MBA model for ADHD predicts that external stimulation increases memory performance for children with ADHD [11].

A growing body of literature supports the notion that external stimulation, specifically music, may have a positive impact on performance for children with ADHD, though the results are not always consistent [12]. Previous studies have demonstrated that background music could be used to improve attention, mood, academic performance, and motor performance for children with ADHD [8-11,13-17]. Abikoff et al., found that children with ADHD performed significantly better on an arithmetic task when music was used as background stimulation, compared to speech as background stimulation. Aydinli et al., [13] demonstrated that both relaxing music and white noise led to improved motor performance compared to silence in children with ADHD. Chew [14] found that pop music in the background increased sustained attention on reading tasks compared to television, classical music, or silence in the background. Greenop & Kann [8] found that children with ADHD who were allowed to choose their favorite music performed significantly better in math performance compared to a no-music, or silent environment. In the Madjar et al., [15] study, children with ADHD performed better on a reading comprehension task and demonstrated decreased heart rate variability when calm music was provided compared to a no-music condition. Pelham et al., [16] found that children with ADHD performed better on academic tasks with music in the background compared to a video or a silent environment. The results of the Soderlund et al. study demonstrated that white noise has a positive impact on the cognitive performance of boys with ADHD, but a negative performance on boys without ADHD. Finally, Zimmerman et al., [17] found that listening to classical music led to decrease in negative mood, whereas a silence condition led to an increase in negative mood and arousal.

Girls with ADHD

Gender differences may play an important role in the diagnosis of ADHD [3,18]. According to the Center for Disease Control, boys are substantially more likely to be diagnosed with ADHD than girls [19]. Only in recent decades have ADHD studies begun to focus on gender differences in ADHD symptomology. (Gershon, 2002) [3,18]. Boys in general are significantly more impulsive than girls; however, no significant differences are found in terms of inattention [18]. Girls with ADHD tend to have lower levels of hyperactivity and lower rates of externalizing behaviors compared to boys [20]. Girls with ADHD also have greater intellectual impairments and more internalizing problems than boys with ADHD, while boys with ADHD have higher ratings on hyperactivity, inattention, impulsivity, and externalizing problems when compared to girls with ADHD (Gershon, 2002).

Purpose of the study

While studies on auditory stimulation for children with ADHD have been conducted, many of the studies were conducted in clinical settings rather than a school setting. Further, studies conducted in a school setting often take place in resource rooms or outside their typical classroom with no other children present.

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As such, the current study will examine the use of auditory stimulation interventions in a more naturalistic classroom setting; the child's regular classroom and with other students present. Further, research on the topic is often limited to mainly boys with ADHD. Additionally, studies examining auditory stimulation interventions in the educational setting for girls with ADHD are even more limited [18], as only one study included girls with ADHD in the educational setting [8]. Due to the limited research, little is known about the impact auditory stimulation has on the academic achievement of girls in the educational setting. Since researchers conducting studies on this topic have focused on boys or have not disaggregated their results, it is unclear whether the interventions being used for boys with ADHD have the same impact and effectiveness for girls with the same disorder. Further research is needed to provide educators with empirically validated interventions to use with girls with ADHD in the school setting. The current study includes only girls with ADHD and examines the impact auditory stimulation interventions have on their mathematical performance in the educational setting. Specifically, the purpose of the current study was to determine if there was a functional relationship between auditory stimulation conditions (i.e., classical music, white noise, noise reduction headphones, and silence) and mathematical performance for girls with ADHD, and to determine the differential effect of the four auditory stimulation conditions.

Method

Participants

Three elementary age girls, Sophia, Reese, and Elizabeth were participants in the current study. Pseudonyms are used to maintain anonymity. All three participants were white, spoke English, and attended school in the western United States. Sophia was 7 years old and in the first grade in a general education classroom and both Reese and Elizabeth were 12 years old and in sixth grade at a middle school. Reese and Elizabeth were in general education classes and in the same class for mathematics. All three participants had a diagnosis of attention deficit hyperactivity disorder from their physicians. Specifically, each participant had a diagnosis of ADHD Predominantly Hyperactive-Impulsive type. No testing had been done by the school district to obtain further information about the diagnoses as none of the participants were receiving special education services, nor had any of the participants been retained in a grade. Only one participant was taking medication throughout the duration of the study. Elizabeth was taking 30mg of Adderall each morning before arriving at school.

Participant Eligibility: Once parental consent was obtained, child assent was also obtained. Additionally, the participants had to be enrolled in elementary or middle school in a general education classroom, as only general education teachers were contacted about sending home consent forms to parents. Participants also had to be diagnosed with ADHD by a physician, psychologist, or psychiatrist in accordance with the Diagnostic and Statistical Manual of Mental Disorders 5th Edition (DSM-5) criteria for ADHD [1]. Furthermore, to be eligible, the participant could only have a diagnosis of ADHD and no other co-occurring disorders. To confirm the diagnosis of ADHD, the Conners 3rd Edition [21] was used with parents and teachers of participants as part of the screening process. To be eligible for the study, participants had to have a T-score of 60 or higher on the following scales of the Conners 3-P and Conners 3-T: Inattention and/or Hyperactivity/Impulsivity; DSM-5 ADHD Inattentive and/or DSM-5 ADHD Hyperactive-Impulsive. A review of school records (e.g., grades and performance on state-wide measures of academic proficiency) was also conducted to determine whether participants had the necessary skills to complete the mathematics worksheets.

AIMS web Mathematics Computation (M-COMP) probes were also used as a screening tool for eligibility: AIMS web Mathematics Computation (M–COMP) is a series of assessments that provide general math computation performance and rate of progress information [22]. M–COMP includes three probes for benchmarking that are meant to be used in the fall, winter, and spring of each school year [22]. M–COMP is a timed, 8-minute, open-ended, paper-based test that was individually administered to each participant. The domains on the probes were dependent on the grade level of each participant, as AIMS web designs probes that are based on grade level. The researcher administered one AIMS web probe to each participant. The purpose of the probes was to determine at what grade level the individual was performing at in terms of math. To be eligible for the study, participants needed to be performing at or above the 50th percentile to ensure the participants were performing near grade level. Sophia earned a score of 42, which is in the 62nd percentile, making her eligible for the study. Reese earned a score of 44, which is in the 72nd percentile, making her eligible for the study. Elizabeth earned a score of 36, which is in the 56th percentile meaning she was also eligible for the current study.

Setting: The current study took place at the participants' elementary and middle schools. All baseline, intervention, and withdrawal sessions were conducted in the participants' classrooms. In the first-grade classroom, Sophia sat at a round table with two of her peers. In the sixth-grade math classroom, Reese and Elizabeth each sat at a square table with two of their peers. The study was completed in the participants' classrooms during normal instructional time with the participants sitting at their seats to make the data collection periods as naturalistic as possible. During all phases of the study the researcher presented materials to the participants and instructed them when to begin, but then moved to the back of the classroom so as not to be a distraction during data collection. The researcher returned to the participants at the end of each of the three-minute sessions.

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Instruments and Materials

Intervention central math worksheet generator

Math worksheets were created using Intervention Central (http://www.interventioncentral.org/teacher-resources/math-work-sheet-generator) and completed by participants during each phase of the study. Intervention Central is a website that provides individuals, teachers, schools, and districts with free resources to help children of all developmental levels in terms of academics and behavior [23]. The Math Worksheet Generator allows an individual to create custom curriculum-based measurement (CBM) math computation probes at any instructional level using the mathematical concepts of addition, subtraction, multiplication, and division. For each type of concept, the generator allows an individual to select different types of problems to be generated. The specific worksheets administered depended on the instructional level of the participants.

Classical music

Classical music was used during one of the intervention conditions of the study. The music played for the entire three minutes of each condition while participants completed the math worksheets. The classical music used for this study was an album titled Mozart: Symphonies Nos. 25, 33, 40 "Great" & 41 "Jupiter" by Wolfgang Amadeus Mozart. This specific album was chosen because it fit the description of "classical," and each of the symphonies on the album contained only instruments being played without vocals. The music was played through headphones using an iPod.

iPod with headphones

To play classical music, a sixth-generation silver, classic iPod was used. The headphones used were white Apple EarPods. Each participant was given a separate set of headphones. According to the National Institute of Deafness and Other Communication Disorders (NIDCD), typical conversations take place between 50-65 dB, and sounds over 75 dB can become intrusive and interfere with hearing [24]. However, iPods do not show a user the decibels at which the music is being played, and there currently is not an exact way to measure the decibels of music on iPods. We did not want to expose the participants to loud music that could interfere with hearing. Therefore, the volume of the music was tested through the iPod headphones by the lead author at varying levels until the music was unobtrusive. The volume was turned up three-fourths of the way. The volume was locked and unable to be changed by participants.

Noise reduction headphones

Many of the noise reduction and noise canceling headphones today are created for the purpose of reducing unwanted ambient sounds while listening to music. For the purposes of this study, the researcher sought headphones that could be used solely as noise reduction headphones to reduce ambient noise without the use of music. The noise reduction headphones chosen for the study were E-a-r 1000 Earmuff – Foam. These headphones have a three-position headband for comfort and durability. The design of the headphones provides a protective seal without excess pressure while the pivoting ear-cup connections help maintain the seal and proper alignment. When worn over the head as intended, the headphones provide a Noise Reduction Rating of 20 decibels as determined by the Canadian Standards Association (CSA), which provides ratings for hearing protective devices.

White noise application

A white noise application was downloaded from the App Store on an iPhone. The application used was titled White Noise (version 5.8.3). This application has a sound catalog of 40 sounds. However, only the "Rainstorm" sound was used with participants. The sound was played through the speakers on the iPhone.

Medication questionnaire

Participants were not asked to discontinue taking any prescribed medication while participating in the study; however, during all phases of the study, a weekly medication questionnaire was sent home to the parents of participants asking about any changes in medication. The purpose of the questionnaire was to monitor any changes in medication to determine if medication effects might have an impact on the results. The medication questionnaire was sent home with the participants on Monday of each week of the study, and they were asked to return the questionnaires by the following Monday of each week. In total, the parents of each participant completed five medication questionnaires.

Dependent variable and dependent measures

Math worksheets were created using Intervention Central and completed by participants during each phase of the study. The worksheets created were used as curriculum-based measurements (CBM) to monitor the participants' progress in mathematics throughout the study. CBMs are used in schools as a means of academic assessment and to monitor and assess students' progress in relation to instruction and intervention [25]. Intervention Central allows individuals to create their own CBMs and specify the types of problems they want to be included in the worksheet. For test-retest reliability, measures should have coefficients greater than .90 for high stakes decision-making and greater than .80 for progress monitoring [26]. Coefficients for alternate-form reliability should be .80 or higher to be acceptable for progress monitoring [26]. The research indicates that randomly generated CBMs from Intervention Central had moderate test–retest reliability and alternate-form reliability [25]. The specific worksheets administered depended on the instructional level of the participants and were created using teacher input to help determine what concepts were appropriate for the participants. The teachers of the participants were shown the types of math concepts and types of problems on the Math Worksheet

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Generator and asked which mathematical concepts their students had learned thus far and what types of problems would be developmentally appropriate for the specific participants. Sophia's teacher indicated that addition and subtraction problems would be the most appropriate for Sophia. Specifically, Sophia's teacher indicated that for addition, two one-digit numbers with sums up to ten would be appropriate. For subtraction, the teacher indicated that two one-digit numbers with sums up to nine would be appropriate. Based on this input, multiple-skill worksheets using addition and subtraction were generated for Sophia with two one-digit numbers with sums up to ten for addition and two one-digit numbers with sums up to nine for subtraction. Sophia's worksheets contained four columns and ten rows of randomized problems.

Reese and Elizabeth's math teacher was the same person. Their teacher provided the same input for both participants. The teacher indicated that mathematical concepts of addition, subtraction, multiplication, and division would be developmentally appropriate. Specifically, for addition and subtraction, the teacher indicated three-digit numbers plus and minus three-digit numbers with regrouping from the ones and tens columns. For multiplication, the teacher indicated that three-digit numbers of times two-digit numbers with no regrouping would be developmentally appropriate. For division, the teacher indicated that three-digit numbers divided by two-digit numbers with no remainder would be developmentally appropriate for the participants. The worksheets were generated based on the teacher's input with four columns and ten rows of problems in a randomized order. Reese and Elizabeth were administered identical worksheets. Data were collected for a total of 10 school days over a 3-week time span, allowing for 10 data points per condition for each participant. On the Intervention Central Math Worksheets, the total number of problems correct, the number of problems attempted, and the number of correct problems divided by the number of problems attempted (accuracy score) was calculated so that intervention performance data could be compared to the baseline data collected.

Experimental Design

A single-case, alternating treatment design was used to determine a functional relationship between the dependent and independent variables following implementation and withdrawal of the independent variables [27,28]. This design involved the concurrent introduction of more than one independent variable during the same intervention phase and allowed for the comparison of the relative effectiveness of more than one independent variable on a single dependent variable. The design in the present study consisted of baseline, intervention, and withdrawal phases.

Baseline phase

The baseline phase of the study was a no stimulation condition in which the participants completed Intervention Central Math Worksheets during normal classroom activities for three minutes. For each participant, normal classroom activities meant the class was working on independent math activities per the teacher's instructions. Therefore, the time of day in which data was collected varied among the participants. The baseline phase of the study lasted until a stable baseline was established for each participant. Data were collected over five days, allowing for five baseline data points for each of the three participants. During the baseline phase of the study, the total number of problems correct, the number of problems attempted, and the number of correct problems divided by the number of problems attempted were calculated so that baseline performance could be compared to the intervention data collected.

Intervention phase

During the intervention phase of the study, participants completed Intervention Central Math Worksheets to determine mathematical performance during four conditions. For each participant, data was collected during classroom math instruction time. Therefore, the time of day of data collection varied among the participants. In the intervention phase, there were four treatment conditions which included: classical music played through an iPod using headphones, noise reduction headphones, white noise from a cell phone application, and silence. In the classical music condition, the music was preselected for participants. They listened to the album titled Mozart: Symphonies Nos. 25, 33, 40 "Great" & 41 "Jupiter" by Wolfgang Amadeus Mozart. Since an alternating treatment design was utilized in this study, all four treatment conditions (i.e., classical music, noise reduction headphones, white noise, and silence) were presented to each participant within each session of the intervention phase. However, the order of the treatment conditions was systematically alternated for each participant during each session with the purpose of controlling for a potential "order" effect. Each condition was presented to the participants for three minutes, with a two-minute break in between each condition. Therefore, each day, the intervention phase of the study lasted 18 minutes for each participant.

Intervention steps

i. Step 1 (3 minutes): Depending on which condition was being administered first, the materials needed for that condition (i.e., iPod with headphones, noise reduction headphones, or white noise application) were checked to ensure they were working properly prior to administering the math worksheet and materials. After checking the materials, the math worksheet was administered to the participant facedown and instructions were read to the participant for the specific condition.

ii. Step 2 (3 minutes): The participant was told to begin and complete the math worksheet during Condition 1, either in silence, while wearing noise reduction headphones, while listening to a white noise application, or while listening to classical music through an iPod. The three-minute condition was timed using a stopwatch.

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iii. Step 3 (2 minutes): The participant was given a two-minute break after Condition 1, which was timed using a stopwatch. During those two minutes, the materials were checked to ensure they were working properly for the next condition.

iv. Step 4 (3 minutes): After checking the materials, the math worksheet was administered to the participant facedown and instructions were read to the participant for the specific condition. The participant completed the math worksheet during Condition 2 either in silence, while wearing noise reduction headphones, while listening to a white noise application, or while listening to classical music through an iPod. The three-minute condition was timed using a stopwatch.

v. Step 5 (2 minutes): The participant was given a two-minute break after Condition 2, which was timed using a stopwatch. During those two minutes, the materials were checked to ensure they were working properly for the next condition.

vi. Step 6 (3 minutes): After checking the materials, the math worksheet was administered to the participant facedown and instructions were read to the participant for the specific condition. The participant completed the math worksheet during Condition 3 either in silence, while wearing noise reduction headphones, while listening to a white noise application, or while listening to classical music through an iPod. The three-minute condition was timed using a stopwatch.

vii. Step 7 (2 minutes): The participant was given a two-minute break after Condition 3, which was timed using a stopwatch. During those two minutes, the materials were checked to ensure they were working properly for the next condition.

viii. Step 8 (3 minutes): After checking the materials, the math worksheet was administered to the participant facedown and instructions were read to the participant for the specific condition. The participant completed the math worksheet during Condition 4 either in silence, while wearing noise reduction headphones, while listening to a white noise application, or while listening to classical music through an iPod. The three-minute condition was timed using a stopwatch.

Withdrawal phase

The withdrawal phase of the study began the day after the intervention phase ended and lasted for three days. For each participant, data was collected during classroom math instruction time. In this phase, the data collection procedures were identical to those used during baseline. The purpose of the withdrawal phase was to examine any changes in math performance when the interventions were removed.

Observer Training And Inter-Observer Agreement (IOA)

One individual, who was not a member of the research team, was trained to be an independent observer to conduct intervention procedural fidelity checks and determine inter-observer agreement (IOA) percentages for Intervention Central Math Worksheet scoring across baseline, intervention, and withdrawal phases. The independent observer was trained in the administration and scoring of the Intervention Central Math Worksheets and the appropriate implementation of the independent variables. During training, the independent observer and the primary author confirmed reliability in the scoring of the Intervention Central Math Worksheets by scoring practice worksheets. Differences in calculations were resolved through discussion. The practice scoring continued until 100% fidelity was obtained. Across participants, the overall IOA for number of attempted problems, number of problems correct, and an accuracy score were 97.8%, 100%, and 97.8% respectively. The overall IOA for number of attempted problems, number of problems correct, and an accuracy score for Sophia's sessions were 100%, 100%, and 100% respectively. The overall IOA for number of attempted problems, number of problems correct, and an accuracy score for Reese's sessions were 93.3%, 100%, and 93.3% respectively. The overall IOA for number of attempted problems, number of problems correct, and an accuracy score for Elizabeth's sessions were 100%, 100%, and 100% respectively. For number of attempted problems, number of correct problems, and accuracy score, the IOA percentages were greater than 90% for all participants.

For the baseline phase, the overall number of problems attempted IOA was 100%. The overall number of correct problems IOA was 100% for the baseline phase, and the overall accuracy score IOA for the baseline phase was 100%. The overall number of problems attempted by IOA for the intervention phase was 97.2%. The overall number of correct problems IOA was 100% for the intervention phase, and the overall accuracy score IOA for the intervention phase was 97.2%. For the withdrawal phase, the overall number of problems attempted IOA was 100%. The overall number of correct problems IOA was 100% for the withdrawal phase, and the overall accuracy score IOA for the withdrawal phase was 100%. The overall number of problems attempted IOA across phases was 99.1%. The overall number of correct problems IOA across phases was 100%. The overall accuracy score across phases was 99.1%. Across all phases the number of problems attempted, number of correct problems, and accuracy score IOA percentages were all greater than 90%.

Procedural Fidelity of the Intervention

Procedural fidelity of the intervention was documented by an independent observer during randomly selected intervention sessions. The purpose of the procedural fidelity check was to ensure the implementation of the independent variables was consistent with the way they were intended to be delivered. This was the same person who participated in the IOA calculations. At the start of each week of the intervention phase, a random number generator was used to determine (for each participant) which intervention sessions the independent observer would be present for. The independent observer was present for a total

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of four intervention sessions, two each week of the intervention phase for each participant. However, the sessions the observer was present for varied for each participant based on the random number generator. During the sessions, the independent observer, via the procedural fidelity checklists, reviewed procedural fidelity. There was a separate checklist for each of the four interventions (i.e., classical music, noise reduction headphones, white noise, and silence) of the intervention phase. Each checklist contained steps from the beginning to the end of the intervention that were examined by the independent observer to ensure that the interventions were being implemented as intended. The steps varied for each intervention based on the materials being used. Across all sessions, six sessions were reviewed for each of the three participants. In the baseline sessions, one worksheet was reviewed per session. In the intervention sessions, Intervention Central Math Worksheets from each of the four conditions were reviewed for the selected session. In the withdrawal sessions, one worksheet was reviewed per session. Therefore, a total of 15 worksheets were reviewed for each participant across all three phases. Each worksheet was reviewed for the number of attempted problems, the number of correct problems, and an accuracy score. It should be noted that each Intervention Central Math Worksheet had an answer key along with the worksheet, which helped determine if problems were correct. For the baseline sessions, the independent observer independently reviewed and scored two sessions for Sophia, Reese, and Elizabeth. For the intervention sessions, the independent observer reviewed and scored three sessions for all the participants. For the withdrawal sessions, the independent observer reviewed and scored one session each for Sophia, Reese, and Elizabeth. Procedural fidelity exceeded 90% across all participants and conditions.

Data Analysis

The effectiveness of the intervention was determined in part through visual inspection of the graphical representation of the data, including the immediacy of change in the DV following the introduction of the IV, the degree of overlap in data points across phases, and an analysis of trend, or the direction of the DV across phases [27,28]. Specifically, to measure change in the dependent variable, visual analysis consisted of examining change in level, trend, variability, and immediacy of change across all participants and all phases of the study. In addition to the visual inspection of the data described above, the magnitude of change in the DV across phases was analyzed by descriptive analysis of mean rates of engagement across phases and through the calculation of the nonparametric effect size metric, PEM. The concept of PEM was introduced by Ma (2006) and is determined by calculating the percentage of intervention data points that exceed the median of the baseline phase (Ma, 2006) [29]. To calculate the PEM scores, the median point is in the baseline data, and a horizontal line is drawn through the baseline and intervention data points. If an uneven data set exists in the baseline phase, the horizontal line will pass through the median data point, but if the baseline data set is even, the horizontal line will fall between the two middle points (Ma, 2006) [29,30]. The horizontal line will pass through the median of the baseline phase and into the intervention phase. The percentage of data points in the intervention phase above the horizontal middle line are calculated to obtain a PEM score if performance is expected to increase; however, if performance is expected to decrease once the intervention is introduced, then the PEM score is the percentage of data points below the horizontal middle line (Ma, 2006). For the current study, since the mathematical performance of each participant is expected to increase with the introduction of the interventions, the percentage of data points in each of the intervention phases above the horizontal middle line were calculated to obtain the PEM. PEM scores range from 0 to 1 and can be interpreted with the following guidelines (Ma, 2006): PEM scores less than 0.7 reflect questionable or not effective interventions; PEM scores between 0.7 and 0.9 reflect moderately effective treatment; and PEM scores ranging from 0.9 to 1 represent highly effective interventions or a large effect.

Results

Sophia

Figure 1 displays Sophia's responding across the four auditory stimulation conditions (classical music, white noise, noise reduction headphones, and silent environment), and across all three dependent variables (number of attempted problems, number of correct problems, and accuracy score). Tables 1-3 display Sophia's mean performance across all three dependent variables. The following section describes Sophia's performance across all four auditory stimulation conditions for each dependent variable.

Attempted problems: The classical music condition (4.60 more items attempted) and white noise condition (3.20 more items attempted) led to the largest improvement in attempted problems for Sophia from baseline (Table 1). PEM between baseline and intervention was .80 for conditions, social music and white noise conditions which indicates that both conditions were moderately effective in increasing the number of attempted problems. The noise reduction headphones and classroom silence conditions led to minimal to no increase in the number of attempted problems for Sophia. PEM between baseline and intervention was .40 and .60 for the noise reduction headphones and classroom silence conditions respectively, which indicates that both conditions were ineffective in increasing Sophia's number of attempted problems. When all auditory stimulation conditions were withdrawn, Sophia's mean performance on accuracy decreased to near baseline levels (1.67 more items attempted compared to baseline).

Correct problems: The classical music condition (7.80 more correct items), white noise condition (5.80 more correct items), and noise reduction headphones condition (3.80 more correct items) all led to substantial improvement in the number of correct problems for Sophia from baseline (Table 2). PEM

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between baseline and the numbervention was 1.00 for the classical music intervention and white noise conditions, and .90 for the noise reduction headphones conditions which indicates that all conditions were highly effective in increasing the number of correct problems for Sophia. PEM between baseline and intervention was .60 for the classroom silence condition, which indicates that it was ineffective in increasing Sophia's number of correct problems. When all auditory stimulation conditions were withdrawn, Sophia's mean performance on number of correct problems increased slightly compared to baseline levels (3.07 more items correct compared to baseline).

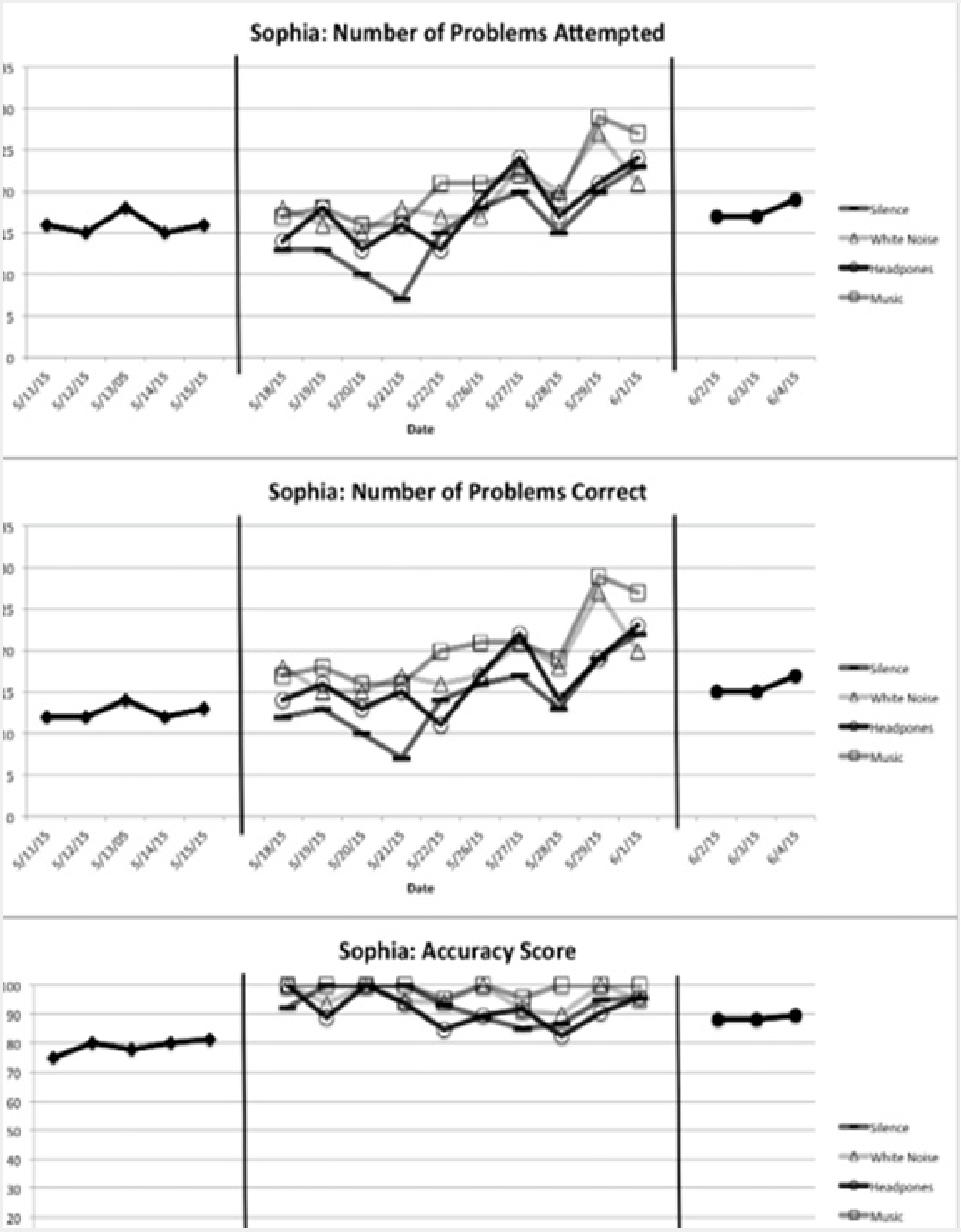

Figure 1: Number of Problems Attempted, Number of Correct Problems, and Accuracy Score on Intervention Central Math Worksheets across Phases (Baseline, Intervention, and Withdrawal) for Sophia. Intervention Conditions: Music, White Noise, Headphones, and Silence.

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Table 1: Mean Attempted Problems for Participants across Phases.

Participant	Baseline	Music	Headphones	White Noise	Silence	Withdrawal
Sophia	16.00	20.60	17.90	19.2	15.40	17.67
Reese	8.60	10.20	8.80	9.80	9.10	8.30
Elizabeth	7.20	10.60	10.00	9.60	9.90	9.00

Table 2: Mean Correct Problems for Participants across Phases.

Participant	Baseline	Music	Headphones	White Noise	Silence	Withdrawal
Sophia	12.60	20.40	16.40	18.40	14.30	15.67
Reese	7.40	9.80	7.70	8.50	7.90	7.33
Elizabeth	6.00	10.10	7.90	8.30	8.00	7.00

Accuracy: Sophia's mean performance on accuracy score increased substantially from baseline to intervention for all four types of auditory stimulation (Table 3). The classical music condition led to the greatest improvement in accuracy (20.26% improvement), followed by white noise condition (17.06% improvement), classroom silence condition (14.87% improvement), and noise reduction headphones (12.90% improvement). PEM between baseline and intervention was 1.00 for all four auditory conditions, which indicates that all conditions were highly effective in increasing accuracy for Sophia. When all auditory stimulation conditions were withdrawn, Sophia's mean performance on accuracy increased slightly compared to baseline levels (9.81% improvement compared to baseline).

Table 3: Mean Accuracy Score for Participants across Phases.

Participant	Baseline	Music	Headphones	White Noise	Silence	Withdrawal
Sophia	78.82	99.08	91.72	95.88	93.69	88.63
Reese	86.12	95.24	87.67	87.02	86.99	87.97
Elizabeth	83.44	95.13	78.39	86.13	79.65	77.60

Reese

Figure 2 displays Reese's responding across the four auditory stimulation conditions (classical music, white noise, noise reduction headphones, and silent environment), and across all three dependent variables (number of attempted problems, number of correct problems, and accuracy score). Tables 1-3 display Reese's mean performance across all three dependent variables. The following section describes Reese's performance across all four auditory stimulation conditions for each dependent variable.

Attempted problems: The classical music condition (1.60 more items attempted) led to the largest improvement in attempted problems for Reese from baseline (Table 1). PEM between baseline and intervention was .80 for the classical music condition which indicates that the music intervention was moderately effective in increasing the number of attempted problems. The noise reduction headphones, white noise, and classroom silence conditions led to minimal to no increases in number of attempted problems for Reese. PEM between baseline and intervention was .40, .60, and .20 for noise reduction headphones, white noise, and classroom silence conditions respectively, which indicates that all three conditions were ineffective in increasing Reese's number of attempted problems. When all auditory stimulation conditions were withdrawn, Reese's mean performance on accuracy decreased to near baseline levels (.30 fewer items attempted compared to baseline).

Correct problems: The classical music condition (2.40 more correct items), and white noise condition (2.10 more correct items) all led to substantial improvement in number of correct problems for Reese from baseline (Table 2). PEM between baseline and intervention was 1.00 for the classical music condition and .80 for the white noise condition, which indicates that the classical music was highly effective, and the white noise condition was moderately effective in increasing number of correct problems for Reese. PEM between baseline and intervention was .60 for the noise reduction headphones condition and classroom silence condition which indicates that they were ineffective in increasing Reese's number of correct problems. When all auditory stimulation conditions were withdrawn, Reese's mean performance on number of correct problems decreased to near baseline levels (.07 fewer items correct compared to baseline).

Accuracy: Reese's mean performance on accuracy increased substantially from baseline to intervention for the classical music condition only (9.12% improvement) (Table 3). PEM between baseline and intervention was .90 for the classical music condition,

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which indicates that it was highly effective in increasing accuracy for Reese. PEM between baseline and intervention was .60 for the noise reduction headphones condition, .40 for the white noise condition, and .60 for the classroom silence condition, which indicates that they were ineffective in increasing Reese's accuracy scores. When all auditory stimulation conditions were withdrawn, Reese's mean performance on accuracy increased slightly compared to baseline levels (1.85% improvement compared to baseline).

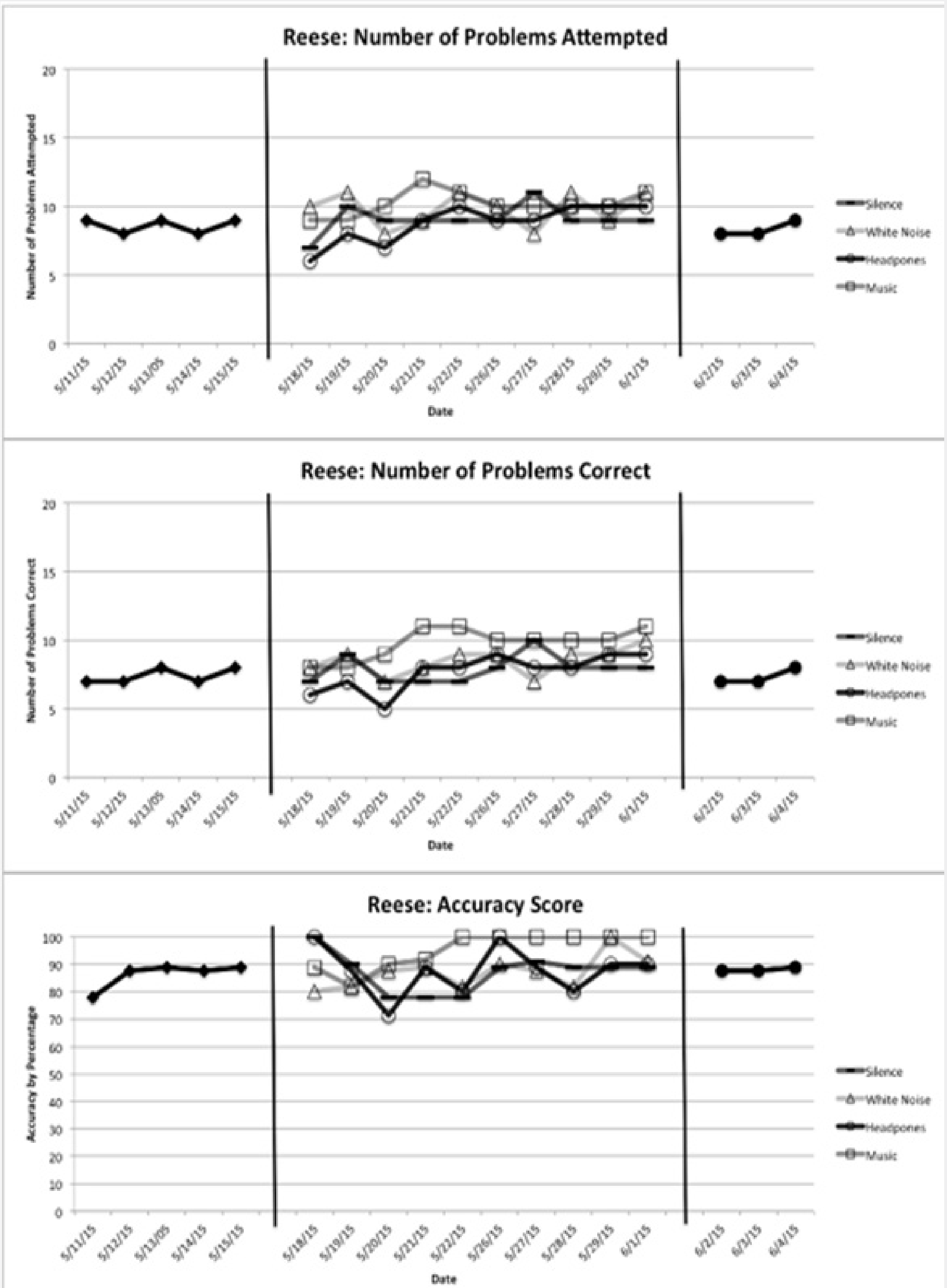

Figure 2: Number of Problems Attempted, Number of Correct Problems, and Accuracy Score on Intervention Central Math Worksheets across Phases (Baseline, Intervention, and Withdrawal) for Reese. Intervention Conditions: Music, White Noise, Headphones, and Silence.

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Elizabeth

Figure 3 displays Elizabeth's responding across the four auditory stimulation conditions (classical music, white noise, noise reduction headphones, and silent environment), and across all three dependent variables (number of attempted problems, number of correct problems, and accuracy score). Tables 1-3 display Elizabeth's mean performance across all three dependent variables. The following section describes Elizabeth's performance across all four auditory stimulation conditions for each dependent variable.

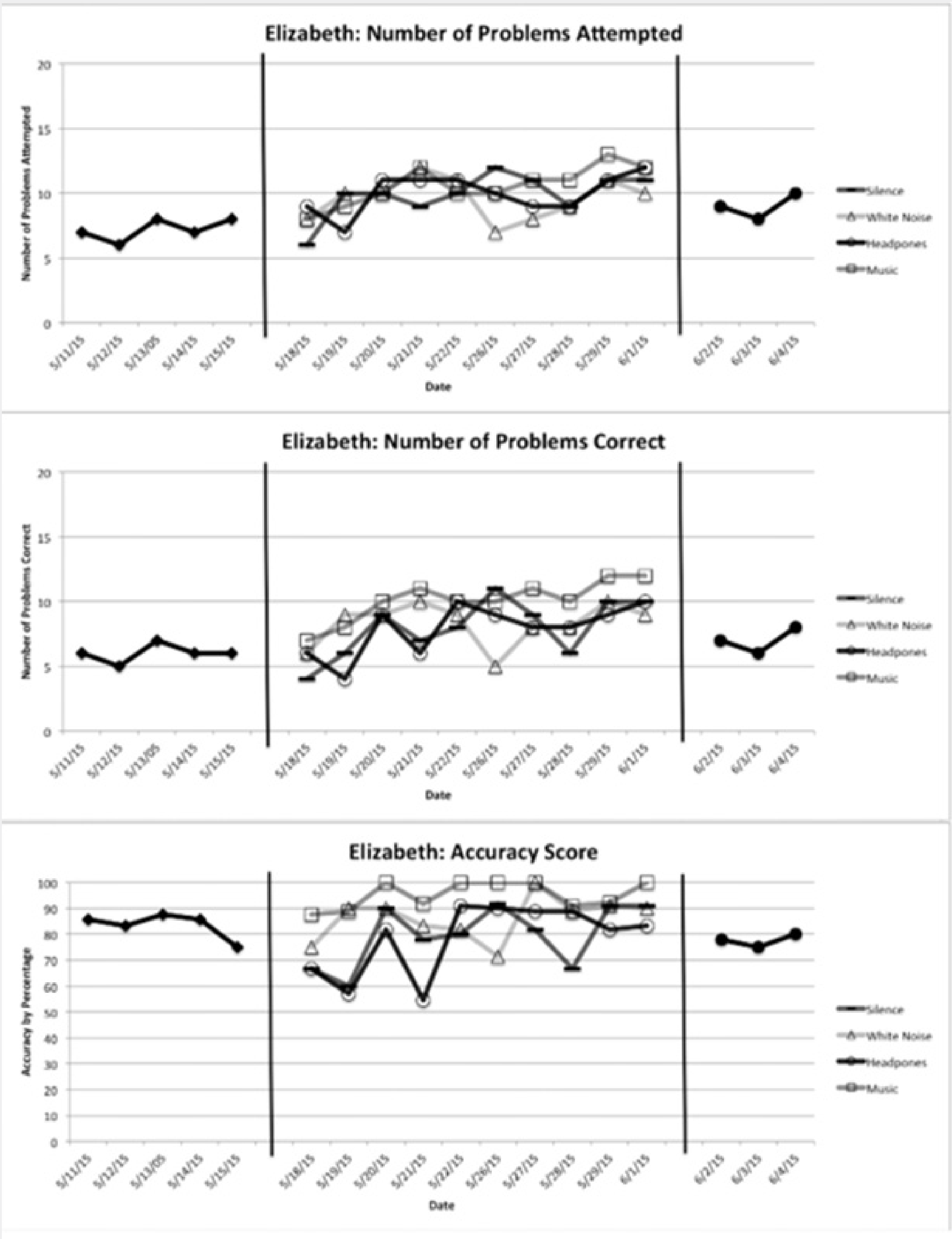

Figure 3: Number of Problems Attempted, Number of Correct Problems, and Accuracy Score on Intervention Central Math Worksheets across Phases (Baseline, Intervention, and Withdrawal) for Elizabeth. Intervention Conditions: Music, White Noise, Headphones, and Silence.

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Attempted problems: Elizabeth's number of attempted problems increased substantially from baseline to intervention for all four types of auditory stimulation (Table 1). The classical music condition (3.40 more items attempted) led to the largest increase in number of attempted problems, followed by the noise reduction headphones (2.80 more items attempted), classroom silence condition (2.70 more items attempted), and white noise condition (1.50 more items attempted). PEM between baseline and intervention was 1.00 for the classical music condition and .90 for the other three conditions, which indicates that all conditions were highly effective in increasing the number of attempted problems for Sophia. When all auditory stimulation conditions were withdrawn, Elizabeth's mean performance on number of attempted problems increased slightly compared to baseline levels (1.8 more items attempted compared to baseline).

Correct problems: All four auditory conditions led to substantial increases in the number of correct problems for Elizabeth compared to baseline (Table 2). The classical music condition led to the highest increase (3.10 more correct items), followed by white noise condition (2.30 more correct items), classroom silence condition (2.00 more correct items), and noise reduction headphones condition. PEM between baseline and intervention was 1.00 for the classical music condition, which indicates that the classical music condition was highly effective. PEM for the white noise condition was .80, and .70 for both the noise reduction headphones condition and classroom silence condition which indicates that they were moderately effective in increasing Elizabeth's number of correct problems. When all auditory stimulation conditions were withdrawn, Elizabeth's mean performance on number of correct problems decreased to near baseline levels (1 more item correct compared to baseline).

Accuracy: Elizabeth's mean performance on accuracy increased substantially from baseline to intervention for the classical music condition only (11.69% improvement) (Table 3). PEM between baseline and intervention was 1.00 for the classical music condition, which indicates that it was highly effective in increasing accuracy for Elizabeth. PEM between baseline and intervention was .40 for the noise reduction headphones condition, .60 for the white noise condition, and .30 for the classroom silence condition, which indicates that they were ineffective in increasing Elizabeth's accuracy scores. When all auditory stimulation conditions were withdrawn, Elizabeth's mean performance on accuracy decreased below baseline levels (-5.85% decrease compared to baseline).

Social validity

To assess social validity, each of the three participants and their teachers completed formative and summative questionnaires. The formative questionnaires were administered during the intervention phase for each participant, while the summative evaluation was administered to each participant post intervention. Based on questionnaire responses during intervention implementation, all three participants indicated that they liked the music intervention the best and the silence intervention the least. The teachers also believed the music intervention was most helpful for the participants, while the silence intervention was least helpful.

Music intervention: In terms of the effectiveness of the music intervention, all three participants strongly agreed that the music intervention helped them remain focused on the math worksheets and strongly disagreed that the intervention was distracting. All three participants also strongly agreed that the music intervention helped improve their math performance and would like the music intervention to be used with other academic work.

White noise: Two participants (Sophia and Reese) agreed that the white noise intervention helped them stay focused on the math worksheets and strongly disagreed that the intervention was distracting. They also agreed that the white noise intervention helped improve their math performance and would like the white noise intervention to be used with other academic work. However, one participant (Elizabeth) disagreed that the white noise intervention helped her remain focused on the math worksheets, but she also did not think the intervention was distracting. She disagreed that the white noise intervention improved her math performance and would not like it to be used with other academic work.

Noise reduction headphones: Two participants (Sophia and Elizabeth) disagreed that the noise reduction headphones intervention helped them stay focused on the math worksheets and believed the intervention was distracting. Both disagreed that the intervention improved their math performance and indicated that they would not like to use the intervention with other academic work. One participant (Reese) agreed that the intervention helped her stay focused on the math worksheets and did not feel the intervention was distracting. However, Reese indicated a similar response to that of the other two participants in terms of intervention effectiveness and future use as she reported that the noise reduction headphones intervention did not improve her math performance and she would not like to use the intervention in the future.

Silence: Based on responses during intervention implementation about the silence intervention, all three participants provided consistent responses. All three participants agreed the silence intervention did not help them stay focused on the math worksheets. However, one participant (Sophia) believed the intervention was distracting while the other two participants (Reese and Elizabeth) did not believe the intervention was distracting. All three participants agreed that the silence intervention did not improve their math performance and none of the participants would like to use the intervention with other academic work.

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Teachers' perspectives intervention effectiveness and feasibility: To assess social validity, the teachers of the participants also completed formative and summative questionnaires. During intervention implementation and following intervention implementation, the teachers of the participants provided information regarding their perspectives on intervention effectiveness and implementation feasibility. The teachers' responses on the questionnaires did not waver during intervention implementation and post intervention implementation. Based on the responses to the questionnaires, the teachers believed the music intervention was most effective for the participants, while the silence intervention was least effective. The teachers believed the participants enjoyed the music, white noise, and noise reduction headphones interventions, but did not believe the participants enjoyed the silence interventions. In terms of implementation and feasibility, the teachers agreed that implementing the music, white noise, noise reduction headphones, and silence interventions would not require too much time away from their teaching. The teachers also indicated that they would implement the music, white noise, and noise reduction headphones interventions in the future. However, the potential of implementing the silence intervention varied. One teacher reported that she would use the silence intervention but felt it might be difficult to implement frequently in a classroom full of other students, while the other teacher indicated that she would not implement the silence intervention.

Discussion

ADHD is a complex neurobehavioral condition affecting up to 10% of the school-aged population. Children and adolescents with ADHD often experience poor performance in school and are often retained in at least one grade prior to high school [5]. Many children with ADHD have the skills necessary to complete academic tasks, but attentional difficulties often lead to poor performance [3]. Inattention, impulsivity, hyperactivity, and other behavioral control difficulties can hinder a child's engagement in learning and lead to academic underachievement compared to their peers [3,4]. Attention is a major component of academic success. For children with ADHD to be successful academically, they must be able to attend to academic tasks. Unfortunately, not all students are able to attend to information on their own and may require specialized interventions, in addition to core instruction, to help them be successful in school. The focus of this current study was to examine the impact of various auditory stimulation interventions on the mathematical performance of girls with ADHD, an under-studied segment of children with ADHD. While using external stimulation to increase performance may seem counterintuitive to conventional wisdom, previous research has found that those with ADHD require more environmental stimulation than others when it comes to task performance because those with ADHD tend to demonstrate higher levels of activity when they encounter a task or situation that evokes low arousal or stimulation. Therefore, the current study utilized a single-case, alternating treatment design across participants to determine if a classical music intervention, noise reduction headphones intervention, white noise intervention, or silence intervention would increase math performance for girls with ADHD.

The results of the current study were generally consistent with previous research on external stimulation [8,10,13-17], particularly in respect to the positive impact of the classical music condition. The classical music condition led to an increase in mathematical performance for all three participants across all three dependent variables. The white noise condition was the second most effective auditory stimuli examined in the current study and generally led to improved math performance for the participants, but the results are less equivocal than the classical music condition. Like the classical music condition, Elizabeth demonstrated an increase in math performance for all three dependent variables in the white noise condition. Sophia demonstrated an increase in mathematical performance during the white noise condition for only the dependent variables of accuracy and number of correct problems, while Reese only improved on the dependent variable of number of correct problems. The silence condition was the third most effective of the auditory stimulations examined in the current study. Sophia and Reese demonstrated an increase in performance for accuracy only during the silence condition. Elizabeth showed an increase in performance for the number of correct problems and the number of attempted problems, but not accuracy. The noise reduction headphones condition was the least effective auditory stimulation condition. Sophia showed an increase in performance for accuracy score only, while Elizabeth showed an increase in performance for the number of attempted problems and the number of correct problems. In contrast, Reese did not show an increase in performance for any of the three dependent variables for the noise reduction headphones condition. When comparing the differential effectiveness of each of the auditory stimulation conditions, the results were consistent for all three participants. When analyzing the classical music condition compared to the white noise condition, noise reduction headphones condition, and silence condition, the classical music condition led to consistently better math performance for all three participants. The white noise condition was also determined to be more effective than the noise reduction headphones intervention or silence conditions at increasing math performance for all three participants. When comparing the noise reduction headphones condition to the silence condition, the results varied for the participants. The noise reduction headphones were more effective than the silence condition for one participant (Sophia), while the silence condition was more effective than the noise reduction headphones condition at increasing overall math performance for two participants (Reese and Elizabeth).

Results from the current study support the Optimal Stimulation Theory proposed by Zentall [6,7]. Zentall proposed that children with ADHD require more environmental stimulation than others

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when it comes to effective performance. The participants received external stimulation using the classical music condition and in turn, their overall math performance increased. In contrast, the participants did not receive external stimulation with the use of the noise reduction headphones intervention and their math performance was significantly lower than the other conditions, particularly the classical music condition. In the noise reduction headphones condition, participants' exposure to external stimulation, such as classroom noise, was significantly reduced. Therefore, the noise reduction headphones did not allow the participants to acquire the external stimulation they may have needed to help increase their overall math performance. The results of the current study, with respect to the white noise condition, were somewhat unexpected considering the underlying tenets of Optimal Stimulation Theory. We did not demonstrate a clear functional relationship between the white noise condition and all three dependent variables, as we did with the classical music condition. One potential explanation could be that the type of white noise could be an important factor in its success. That is, the type of white noise used in the current study, rain sounds, may not have been stimulating or may have been distracting for Sophia and Reese, but not for Elizabeth.

The social validity of auditory stimulation interventions

The empirical results of the current study provide support for the effectiveness of the music intervention in terms of increasing math performance for all participants, and participants' responses to social validity questionnaires corroborate this finding. All three participants indicated that they liked the music intervention and strongly agreed that the music intervention helped them remain focused on the math worksheets, as well as improved their math performance. Moreover, this study only provided support in terms of the effectiveness of the white noise intervention for one participant (Elizabeth). Elizabeth did not believe the white noise intervention increased her math performance, while the other two participants (Sophia and Reese) believed the intervention improved their performance. During the post intervention social validity questionnaires, the current study also did not provide support for the noise reduction headphones intervention or the silence intervention for any of the participants, and the responses of the participants mirror these findings. Furthermore, two participants (Sophia and Reese) indicated that they would have liked different music to be used during the classical music intervention. The two classroom teachers also completed social validity questionnaires in which they indicated that the music intervention was the most helpful intervention for the participants, while the silence intervention was least helpful. They also felt the participants enjoyed the music, white noise, and noise reduction headphones interventions, but did not believe the participants enjoyed the silence intervention. In terms of implementation and feasibility, the teachers agreed that implementing the music, white noise, noise reduction headphones, and silence interventions would not require too much time away from their teaching, but the potential of implementing the silence intervention varied. One teacher reported that she would use the silence intervention, but felt it might be difficult to implement frequently, while the other teacher indicated that she would not implement the silence intervention. Both teachers indicated that they would have no problem using the other three interventions in the future.

Implications for practitioners

One important implication for practitioners from the current study is to consider the utility and potential benefit of external stimulation for children with ADHD. Parents of children with ADHD often describe how their children prefer the presence of external stimulation, such as the television or stereo while completing homework tasks, but parents express concern that the external stimulation could hinder the academic performance of their children [10]. Results of this study, and other previous studies, may contradict what parents believe should be most effective for children with ADHD; namely that children with ADHD should work in a quiet setting, free of distraction. However, in this study, the silence and noise reduction headphones condition did not lead to improvements in math performance for participants in the current study. In contrast, the use of auditory stimulation in the form of classical music and white noise led to improved math performance for the girls with ADHD participating in the current study.

Limitations of the Current Study and Suggestions for Future Research

Several limitations were noted in the current study.

i. First, the study employed a single case research design to examine a potential functional relationship between auditory stimulation and math performance with a specific population (girls ages 7 to 12 with ADHD and no co-occurring disorders). While a single-case research design was the appropriate choice for this study given our purpose, there are limitations associated with the use of single-case research design that should be discussed. A lone single-case design study limits external validity, and thus caution should be used when generalizing the results to other children with ADHD. In single-case research design, external validity is established via a rich description of participants, settings, and procedures, and via replication. As such, further replication studies should be conducted which apply the same intervention procedures and use the same population of children. Additionally, the study only incorporated girls with ADHD to address a limitation in previous research. The use of a gender-specific participant pool limits our ability to generalize the results to boys with ADHD. Future research should also attempt to replicate the current study with a broader population of children with ADHD.

ii. Another limitation of the current study is that it was implemented by a university research team who was explicitly trained in the implementation and progress-monitoring

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techniques used in the current study. In most cases, if these auditory stimulation interventions were implemented in a school setting, a teacher or other member of the school team would be implementing the intervention and collecting data. While both teachers reported that the intervention seemed feasible to implement in the school setting, they did not implement the interventions themselves in the current study. Future research should include teachers in a more prominent role, including as the implementers of the auditory stimulation intervention.

iii. A third limitation, and potentially confounding variable, is that the participants were not asked to discontinue prescribed medication during the study. Only one participant, Elizabeth, was taking medication, a 30mg dose of Adderall, to help with her symptoms of ADHD. However, the use of medication could have caused Elizabeth to be more focused, which is one of the goals of Adderall. Therefore, her performance may have been impacted by using the medication. While participants were not asked to discontinue prescribed medication, any changes in medication use were monitored during each week of the study for each participant. Future research should control the participants' use of medication to better determine if any medication effects exist.

iv. A fourth limitation of the current study is that only one type of music (classical) was implemented during the intervention phase of the study. Similarly, only one type of white noise (rain sounds) was utilized in the current study. Therefore, the current study cannot be generalized to other types of music other than classical music and cannot be generalized to other types of white noise. Future research should consider using other genres of music, and multiple types of white noise, or perhaps even brown noise, to determine the differential impact of these variables on the academic performance of children with ADHD.

v. A final limitation of the current study is that we examined the effect of auditory stimulation on just one academic area, mathematics, and one area of mathematics, computation. Future research should examine the impact of auditory stimulation interventions on other mathematical concepts, such as applied problems, and on other academic areas as well, such as reading and written language. In school, children with ADHD may have difficulties in more than one academic area. It would be beneficial to know if auditory stimulation could be used across all academic areas for those with ADHD.

Summary

The purpose of the current study was to determine if there was a functional relationship between auditory stimulation conditions (i.e., classical music, white noise, noise reduction headphones, and silence) and mathematical performance for girls with ADHD, and to determine the differential effect of the four auditory stimulation conditions. The results of the current study demonstrated that the use of auditory stimulation interventions for children with ADHD, particularly, the use of classical music, could improve the math performance of girls with ADHD. The classical music condition led to an increase in mathematical performance for all three participants across all three dependent variables and was differentially more effective than the other three auditory stimulation conditions used in the study (white noise, noise reduction headphones, and silence). The current study also provided support of the social validity of the music intervention based on participant reports on the social validity questionnaires. The child participants and their teachers indicated that they enjoyed using the music intervention, that it helped them to better focus on their work, and that it improved their math performance. However, several limitations of the current study were noted, and future research is needed to address these limitations and to further elucidate the participant, setting, and procedural variables that lead to the most beneficial outcomes for children with ADHD.

References

1. American Psychiatric Association (2013) Diagnostic and statistical manual of mental disorders (5th edn.) Arlington, VA: American Psychiatric Publishing.
2. Danielson ML, Bitsko RH, Ghandour RM, Holbrook JR, Kogan MD, et al. (2018) Prevalence of Parent-Reported ADHD Diagnosis and Associated Treatment Among U.S. Children and Adolescents, 2016. J Clin Child Adolesc Psychol 47(2): 199-212.
3. DuPaul GJ, Stoner G (2003) ADHD in schools' assessment and intervention strategies (3rd edn). The Guilford Press New York.
4. Barkley RA (Ed) (2018) Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment (4th edn.) Guilford Press.
5. Barkley RA, Murphy KR, Fischer M (2008) ADHD in adults: What science says. New York, NY: Guilford Press.
6. Zentall S (1975) Optimal stimulation as a theoretical basis of hyperactivity. Am J Orthopsychiatry 45(4): 549-563.
7. Zentall S (1993) Research on the educational implications of ADHD. Exceptional Children 60(2): 143-153.
8. Greenop K, Kann L (2007) Extra-task stimulation on mathematics performance in children with and without ADHD. South Afr J Psychol 37(2): 330-344.
9. Thompson WF, Schellenberg EG, Husain G (2001) Arousal, mood, and the Mozart effect. Psychol Sci 12(3): 248-251.
10. Abikoff H, Courtney ME, Szeibel PJ, Koplewicz HS (1996) The Effects of Auditory Stimulation on the Arithmetic Performance of Children with ADHD and Nondisabled Children. J Learn Disabil 29(3): 238-246.
11. Soderlund G, Sikstrom S, Smart A (2007) Listen to the Noise: Noise Is Beneficial for Cognitive Performance in ADHD. J Child Psychol Psychiatry 48(8): 840-847.
12. Maloy M, Peterson R (2014) A Meta-Analysis of the Effectiveness of Music Interventions for Children and Adolescents with Attention-Deficit/Hyperactivity Disorder. Psychomusicol Music Mind Brain 24(4): 328-339.
13. Aydinli FE, Çak T, Kirazli MÇ, Çinar BÇ, Pektaş A, et al. (2018) Effects of distractors on upright balance performance in school-aged children with attention deficit hyperactivity disorder, preliminary study. Braz J Otorhinolaryngol 84(3): 280-289.
14. Chew C (2010) Using EEG recordings to examine the relationships between sustained attention and types of background music in individu-

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als with ADHD. Proceedings of Measuring Behavior p. 52-54.

15. Madjar N, Gazoli R, Manor I, Shoval G (2020) Contrasting effects of music on reading comprehension in preadolescents with and without ADHD. Psychiatry Res 291: 113207.
16. Pelham WE, Waschbusch DA, Hoza B, Gnagy EM, Greiner AR, et al. (2011) Music and Video as Distractors for Boys with ADHD in the Classroom: Comparison with Controls, Individual Differences, and Medication Effects. J Abnorm Child Psychol 39(8): 1085-1098.
17. Zimmermann MB, Diers K, Strunz L, Scherbaum N, Mette C (2019) Listening to Mozart Improves Current Mood in Adult ADHD - A Randomized Controlled Pilot Study. Front Psychol 10: 1104.
18. Hasson R, Fine JG (2012) Gender Differences among children with ADHD on continuous performance tests: A meta-analytic review. J Atten Disord 16(3): 190-198.
19. Bitsko RH, Claussen AH, Lichstein J, Lindsey IB, Sherry Everett J, et al. (2022) Mental health surveillance among children-United States, 2013–2019. MMWR Suppl 71(2): 1-48.
20. Gaub M, Carlson CL (1997) Gender differences in ADHD: A Meta-Analysis and Critical Review. J Am Acad Child Adolesc Psychiatr 36(8): 1036-1045.
21. Conners CK, Jenni P, Sara R Rzepa (2008) Conners 3rd Edition Toronto, Ontario, Canada: Multi-Health Systems. Encyclop Clin Neuropsychol 675-678.
22. Pearson (2012) AIMS web math computation administration and scoring guide p. 10.
23. Intervention Central (2012) Math work-math worksheet generator.
24. National Institute on Deafness and Other Communication Disorders (NIDCD) (2014) Common Sounds.
25. Strait GG, Smith BH, Pender C, Malone PS, Roberts J, et al. (2015) The reliability of randomly generated math curriculum-based measurements. Assess Effective Interven 40(4): 247-253.
26. Foegen A, Jiban C, Deno S (2007) Progress monitoring measures in mathematics. J Special Education 41(2): 121-139.
27. Kazdin AE (2011) Single-case research designs: Methods for clinical and applied settings. Oxford University Press New York.
28. What Works Clearinghouse (2020) What Works Clearinghouse Standards Handbook, Version 4.1. Washington, DC: US Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance. Washington, DC: US.
29. Parker RI, Vannest KJ, Davis JL (2011) Effect size in single-case research: A review of nine nonoverlap techniques. Behav Modif 35(4): 303-322.
30. DuPaul GJ (2007) School-based interventions for students with attention deficit hyperactivity disorder: Current status and future directions. School Psychol Rev 36(2): 183-194.

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