University of Wollongong
Research Online

Faculty of Social Sciences - Papers | Faculty of Social Sciences

2018

Effect of Neurocognitive Training for Children With ADHD at Improving Academic Engagement in Two Learning Settings

Han Jiang
Zhejiang Normal University, hjiang@uow.edu.au

Stuart J. Johnstone
University of Wollongong, sjohnsto@uow.edu.au

Li Sun
Peking University

Dawei Zhang
University of Wollongong, dwz847@uowmail.edu.au

Publication Details

Jiang, H., Johnstone, S. J., Sun, L. & Zhang, D. (2018). Effect of Neurocognitive Training for Children With ADHD at Improving Academic Engagement in Two Learning Settings. Journal of Attention Disorders, online first 1-18.

Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au

Effect of Neurocognitive Training for Children With ADHD at Improving Academic Engagement in Two Learning Settings

Abstract

Objective: This preliminary study investigated effectiveness of neurocognitive training on academic engagement (AET) for children with ADHD. The training approach targeted working memory, inhibitory control, and attention/relaxation (via brain electrical activity).

Method: A reversal design with a 2-week follow-up was used to assess the effectiveness of the treatment on two children with diagnosed ADHD in two learning settings. Direct observation was used to collect academic-related behavior.

Results: Improvements in on-task expected behavior (ONT-EX) and general AET, as well as reductions in off-task motor activity (OFF-MA) and off-task passive behavior (OFF-PB) were observed for both students over baselines and across the settings. Moreover, differences in behavioral change were found between participants and settings.

Conclusion: These findings support using the treatment for improving academic performance of children with ADHD. Future studies may investigate influences of contextual differences, nontreatment variables, or adult's feedback during the training session on treatment effectiveness.

Disciplines

Education | Social and Behavioral Sciences

Publication Details

Jiang, H., Johnstone, S. J., Sun, L. & Zhang, D. (2018). Effect of Neurocognitive Training for Children With ADHD at Improving Academic Engagement in Two Learning Settings. Journal of Attention Disorders, online first 1-18.

This journal article is available at Research Online: https://ro.uow.edu.au/sspapers/4422

This article originally published as: Jiang, H., Johnstone, S. J., Sun, L. & Zhang, D. (2018). Effect of Neurocognitive Training for Children With ADHD at Improving Academic Engagement in Two Learning Settings. *Journal of Attention Disorders*, online first 1-18.

Abstract

This preliminary study investigated effectiveness of neurocognitive training on academic engagement for children with AD/HD. The training approach targeted working memory, inhibitory control, and attention/relaxation (via brain electrical activity). A reversal design with a two-week follow-up was used to assess the effectiveness of the treatment on two children with diagnosed AD/HD in two learning settings. The results of direct observation indicated improvements in on-task expected behavior (ONT-EX) and general academic engagement (AET), as well as, reductions in off-task motor activity (OFF-MA) and off-task passive behavior (OFF-PB) for both students over baselines and across the settings. Moreover, differences in behavioral change were found between participants and settings. These findings support using the treatment for improving academic performance of children with AD/HD. Future studies may investigate influences of contextual differences, non-treatment variables or adult's feedback during the training session on treatment effectiveness.

Keyword: AD/HD; neurocognitive; training; EEG; neurofeedback; academic engagement; learning settings

Effect of neurocognitive training for children with AD/HD at improving academic engagement in two learning settings

Attention-deficit hyperactivity disorder (AD/HD) is one of the most common developmental disorders of childhood. About 5% of school children are affected by this disorder, with boys two times more likely to be diagnosed than girls (American Psychiatric Association, 2013). The core symptoms are age-inappropriate and persistent patterns of inattentive, impulsive, and hyperactive behaviors. Children with AD/HD often encounter impairments in school performance, including lower academic achievement (Langberg et al., 2011; Rodriguez et al., 2007), poorer relatedness (e.g., low belongingness with the teachers) in the classroom (Rogers & Tannock, 2013), a higher level of graduation failure (Pingault, Côté, Vitaro, Falissard, Genolini, & Tremblay, 2014), and a larger proportion of school suspension or expulsion (Parker et al., 2015).

During a lesson, typically-developing children can remain on-task during academic activities, and quickly and easily switch from off-task to on-task. Children with AD/HD, however, may display dysfunctions in these attentive traits (Imeraj et al., 2013). In addition, when compared with typically-developing peers, children with AD/HD have demonstrated significantly lower levels of sustained attention (Egeland, Johansen, & Ueland, 2009), and significantly higher levels of off-task behavior (Kofler, Rapport, & Alderson, 2008), motoric activities (e.g., rolling chair, leaving seat; Sarver, Rapport, Kofler, Raiker, & Friedman, 2015), and disruptive behaviors (Liu, Huang, Kao, & Gau, 2017). Severities of off-task behavior are associated with different levels of inattention displayed by children with AD/HD. Rapport, Kofler, Alderson, Timko, and DuPaul (2009) found that children with severe inattentive symptoms, in comparison with peers with less severe inattentive symptoms, spent twice as long off-task. According to Rapport, Scanlan, and Denney's (1999) research on developmental pathways of AD/HD, inattentive behaviors, rather than other symptoms (e.g., disruption) are related to later academic underachievement.

Observational studies have indicated that specific learning contexts have differentiated impacts on academic engagement. While children with AD/HD exhibited less on-task behavior compared to their typically developed peers, Vile Junod, DePaul, Jitendra, Volpe, and Cleary (2006) reported that the most significant discrepancy was in activities of passive engagement (e.g., silently reading academic material), rather than in activities of active engagement (e.g., talking to a teacher about academic material). In a regular lesson, Lauth, Heubeck, and Mackowiak (2006) reported that children with AD/HD exhibited less time on-task in inconspicuous tasks (e.g., doing math) as compared to the non-AD/HD peers. Surprisingly, the engagement rate of the AD/HD group was higher in self-initiated activities (e.g., correcting a peer), and more than two times as high as the non-AD/HD group in other-initiated activities (e.g., answering a question). When academic content was concerned, Imeraj and colleagues (2013) reported that children with AD/HD were on-task less during academic lessons (e.g., mathematics, language, sciences) compared to typically developing peers. Besides, such a discrepancy was not found in non-academic lessons (e.g., music, arts). These studies suggest that off-task behavior in children with AD/HD may be influenced by the learning context. DuPaul and Joshua (2015) indicated that children with AD/HD tend to respond poorly in contexts that lack scaffolding, have high executive functioning demand, or require high self-regulation.

Academic engagement in children with AD/HD has been shown to vary based on different instructional contexts. In a regular lesson, children with AD/HD exhibited a higher rate of inattentive off-task behavior (e.g., day-dreaming) during whole class instruction, whereas these children displayed a higher level of disruptive off-task behavior (e.g., leaving seat) during instructions with minimal interaction (e.g., silent work; Lauth et al., 2006). It is possible that instructional settings such as silent work (that involve less external support such as teacher feedback) or instructional settings such as whole class teaching (that involve less teacher supervision), are more likely to trigger off-task behaviors in children with AD/HD. More recently, several studies (Hart, Massetti, Fabiano, Pariseau, & Pelham, 2011; Imeraj et al., 2013) have identified effects of group size on academic performance in children with AD/HD. For example, Hart et al. (2011) reported that the rate of on-task behavior was higher in small group than in independent silent work or whole class instruction. However, the positive relationship between small group instruction and academic achievement (via calculating test accuracy) in children with AD/HD was not established in this study. In fact, test accuracy was lower in small group instruction than the other two group sizes.

Neurocognitive training for children with AD/HD

Non-pharmacological treatments for AD/HD have been developed in several modalities, such as cognitive training (CT) and neurofeedback training (NF). CT involves the use of purpose-designed computer software to exercise particular cognitive abilities (e.g., working memory, inhibitory control). These tasks typically include performance feedback, with task difficulty varied according to performance to promote challenge, engagement, and learning. Some positive effects of this approach have been reported in specific cognitive abilities, behavioral outcomes, and academic achievements (Rapport, Orban, Kofler, Friedman, & Bolden, 2015).

NF is an innovative approach that builds on the premise that functional states of brain activity (e.g., attention) can be modified through self-regulation of brain electrical activity (electroencephalogram [EEG]; Lofthouse, Arnold, Hersch, Hurt, & DeBeus, 2012). Research has identified certain types of EEG activity that are associated with the core symptoms of AD/HD (see the review by Barry, Clarke, & Johnstone, 2003). The typical goal of NF in AD/HD is enhancing higher frequency brain activity (e.g. alpha and beta) and inhibiting lower frequency activity (e.g. theta and delta). Relatively new consumer-level EEG recording devices allow for simple, valid, and reliable measurement of brain activity (Johnstone, Blackman, & Bruggemann, 2012; Rogers, Aminov, Wilson, & Johnstone, 2016) that can be used in conjunction with computer software to achieve NF goals. A growing body of research has reported that NF promotes cognitive functions, improves AD/HD symptoms, and psychosocial outcomes (e.g., self-regulation skills; see reviews by Lofthouse et al., 2012;

Mayer, Wyckoff, & Strehl, 2013). A meta-analytic review of non-pharmacological treatments for AD/HD (Hodgson, Hutchinson, & Denson, 2014) suggested that NF outperforms some other types of treatments (e.g., behaviour modification, parent training) in the average weighted effect size of outcome measures.

The training approach used in the current study brings together CT and NF to exercise and improve cognitive and state-control functions; due to this combination of training targets it is referred to as “neurocognitive” training. The neurocognitive approach is built on the cognitive energetic model (CEM) of AD/HD (Sergeant, 2005a, 2005b), which proposes that AD/HD stems from a state-regulation dysfunction that affects efficient engagement of computational/cognitive processes and executive functions. The neurocognitive approach targets fundamental cognitive processes such as working memory and inhibitory control, as well as the psychological state factors of attention and relaxation via NF (Johnstone, 2013). When functioning effectively, these processes interact to provide a foundation for an individual’s effective engagement with information in their external world. It is thought that targeting these three areas in each training session will take advantage of the dynamic interplay between them, as outlined by CEM, resulting in improved processing abilities in these areas and better training outcomes.

Early work examined the efficacy of CT targeting both working memory and inhibitory control in children with AD/HD (Johnstone, Roodenrys, Phillips, Watt, & Mantz, 2010). Thirty-eight children diagnosed with the combined presentation (AD/HD-C) undertook 25 training sessions at home using purpose-built software over a 5-week period. Each training session included six games of a response inhibition task and six games of a working memory task. After training, the participants had improved resting EEG, and their parents and another potentially less-biased adult observer (such as grandparent, aunt/uncle, or family friend with 1-2 contact hours with the child per week) rated significant improvements on AD/HD symptoms. A subsequent CT study added passive attention-monitoring to the cognitive training via a portable, wireless, dry-sensor EEG recording device (Johnstone, Roodenrys, et al., 2012) to allow feedback based on task performance and attention level during the task. After training, significant improvements in spatial working memory, ignoring distracting stimuli, and sustained attention were measured in the training cohorts compared to the waitlist. In addition, the training cohorts showed significant improvements in AD/HD symptoms as rated by their parents and another potentially less-biased adult observer.

A preliminary study of the combined CT and NF (i.e. neurocognitive) approach reported behavioral and academic outcomes of 5 Chinese primary school children with AD/HD. The participants undertook 25 training sessions using purpose-built software over a 5- to 7-week period at home. Each training session contained 14 games: 4 working memory, 4 inhibitory control, and 6 NF (2 for attention, 2 for relaxation, and 2 for combined attention and relaxation). After training, the participants showed reduced AD/HD symptoms and other problem behaviors (e.g., social problems) as rated by their parents and teachers. The participants also showed increased rates of assignment completion during the training and a 4-week follow-up, in comparison with baseline. Recently, in a randomized control study of the neurocognitive approach with a larger sample size (n=85; Johnstone, Roodenrys, Johnson, Bonfield, & Bennett, 2017), children in the training condition showed substantial improvements in AD/HD symptoms and related behaviors such executive functions, aggression, and externalizing behaviors. There were minor improvements in two of six neartransfer tasks, evidence of far-transfer of training effects in four of five far-transfer tasks, and indications of normalization of atypical EEG features after training.

At present, most studies have reported the effects of neurocognitive training on academic behaviors (except dependent variable ‘homework completion’ in Jiang & Johnstone, 2015) based on adult’s reports of child behavior via checklists (Rapport, Orban, Kofler, & Friedman, 2013). No studies have been conducted to establish a causal relationship between neurocognitive training and observed learning behaviors. Studies examining the effect of NF on academic engagement behaviors via direct observation are also limited (see reviews Cortese et al., 2016; Hodgson et al., 2014). Two randomized control studies examined effects of computer-based NF or computer-based attention (cognitive) training in elementary (Steiner, Frenette, Rene, Brennan, & Perrin, 2014) and middle school students (Steiner, Sheldrick, Gotthelf, & Perrin, 2011). In both studies, academic engagement (active or passive) and off-task behaviors (motor, verbal, and passive) were observed at three phases, i.e., before, during, and 6-months after the interventions. The results of two studies showed improvements in academic engagement and off-task behaviors for the NF conditions compared to waitlist. Nonetheless, without illustrating observed data for each behavior across phases, the findings of these studies could not indicate deviations among these behaviors. It was unclear which specific behavior(s) were improved by the use of NF.

The purpose of this study

Despite a growing body of research supporting the use of neurocognitive training for improving cognitive functions and reducing AD/HD symptoms (Chacko, Kofler, & Jarrett, 2014), relatively little research has been conducted examining classroom learning behaviors. The primary purpose of this study was to extend evaluation of neurocognitive training outcomes into a real-life educational context. Chacko and colleagues (2014) proposed “next generation neurocognitive training” would provide “the cortical foundation to improve children’s ability to fully benefit from adjunctive, skill-based approaches intended to ameliorate the behavioral, academic, and interpersonal manifestations of the complex interactions between underlying neurocognitive impairments and the child’s environment” (p. 369). This study was inspired by such a prospect. Further, we wanted to investigate behavioral outcomes of the current training protocol in learning contexts. It was expected that findings of this study might provide implications for scaffolding updated training protocols.

Thus, the primary research objective of present study was to examine the effects of neurocognitive training on academic engagement behavior. Specifically, we anticipated increasing on-task behaviors and reducing off-task behaviors through neurocognitive training and tested whether the effects occurred through a reversal design with a 2-week follow-up.

The secondary research objective was to examine the behavioral outcomes of the training in different learning contexts. In the present study, we purposefully selected a self-study room and small classroom as the research contexts. The main difference between the two contexts was the presence (or not) or external distraction. The small class context had potential distractors (e.g., interruption by other students, discussion between teacher and students for solving an academic problem) as it contained other students, while the self-study room did not. It was hoped that assessing the impact of the training in these two contexts would have relevance for learning practice.

Method

Setting and Participants

The training was conducted in an after-school care center attached to a public primary school in an urban area in East China. The center provided after school services for students who had difficulties with their homework (between 3 pm and 7 pm), including assistance with academic learning, supervision of homework completion, and extra-curricular teaching. These services were allocated by two types of placement: small class (between 10 to 15 students) and one-to-one instruction (one teacher to one student). Students who exhibited more disruptive behavior and/or severe learning difficulties might be placed in the one-to-one instruction. To attend this program, students were initially referred by their teachers due to difficulties in completing their homework (e.g., procrastination, low accuracy). Assessment of the students' academic outcomes and behavioral problems were then conducted for their placements. Students might be involved in more than one placement based on their performance on different tasks. The program contained 6 teachers and 41 students ranging from grade 1 to grade 6.

The participants were randomly selected from a pool of qualified students who were diagnosed with AD/HD and studying in inclusive classrooms. These students often had learning difficulties. Some of them were at risk of academic failure. Student A was a 6-year old first-grader, and had attended the after-school program for two months. He received one-to-one instruction for most of his time in the center due to his disruptive behavior. His teachers and parents were concerned about his problem behaviors in engaging classroom teaching, class work and homework completion, organization, and inappropriate social interactions with peers (e.g., pushing). According to the homeroom teacher, the student was off-task most of the time during class. His off-task behaviors included playing with toys, interrupting teachers/peers, and hiding/wandering in class. He could not complete any in-class assignment without teacher supervision. Before attending this program, his father spent about two or three hours every day helping with his assignments at home. The student was diagnosed with AD/HD-C without comorbidities. On his recent evaluation, he obtained a full-scale IQ of 68 on the Wechsler Intelligence Scale for Children–Third Edition (Chinese version; WISC-IV; Wechsler, 2003), and Inattention subscale of 1.67, Hyperactivity/Impulsivity subscale of 1.56, and Oppositional subscale of 0.5 on parent-rating SNAP-IV (Chinese version; Swanson et al., 2001). The student was not taking medication or receiving other treatment for AD/HD during this study.

Student B was a 10-year old five-grader. He had attended the program for one year, and spent most of his time in small class instruction with occasional one-to-one instruction. His classroom misbehavior included daydreaming, playing small toys, avoiding tasks, and sleeping. According to the homeroom teacher, the student was easily distracted by noises, people, or things that were irrelevant. He also avoided assignments that he was not good at (e.g., English grammar) or uninterested in (e.g., writing). The student was diagnosed with the predominantly inattentive presentation without comorbidities (AD/HD-I). On his recent evaluation, he obtained a full-scale IQ of 87 on the WISC IV (Chinese version; Wechsler, 2003), and Inattention subscale of 2.11, Hyperactivity/Impulsivity subscale of 0.67, and Oppositional subscale of 0.75 on parent-rating SNAP-IV (Chinese version; Swanson et al., 2001). The student was not taking medication or receiving other treatment for AD/HD during this study.

Independent variable

The independent variable in this study was the computerized neurocognitive training, implemented with adult feedback. The training protocol consisted of 25 sessions. Each session consisted of 14 games: 8 CT (i.e. 4 working memory, 4 inhibitory control) and 6 NF. The 6 NF games included 2 that were controlled by attention level, 2 controlled by relaxation level, and 2 controlled by combined attention and relaxation index (termed *Zen*). The working memory games involved holding information in memory with subsequent recall to complete an action. The inhibitory-control games required a tap/press response to frequently presented “Go” stimuli and the withholding of responses to infrequent “Nogo” stimuli. The NF games required children to be attentive, relaxed, or in a “Zen” state (i.e., both attentive and relaxed), with game-play linked to levels of these EEG-derived factors. Completing a session took 15 to 20 minutes. The difficulty level of each game increased with successful completion of the previous level and decreased if the previous level was not successfully completed. All games started at the lowest level of difficulty. Feedback was provided to the child at the end of each game in the form of a star rating. Zero to 5 stars were awarded based on performance, linked to Go/Nogo errors, reaction time, and attention level in the inhibitory-control games, search errors and attention level in the working memory games, and threshold level and time-above-threshold in the NF games.

The training was conducted in a consistent environment to minimize external distraction. All sessions were conducted between 3 and 5 pm. The student had a break time of 45min (including had snack and beverage, and play time) between the school and training sessions. If a student felt tired during the training, he was allowed to pause the training and rest for a few minutes before he restarted the training. Each participant completed the sessions in a quiet self-study room.

A teacher was trained to provide positive feedback to the participants 5 times per session. The feedback was of the following types: 1. Student performance on previous task, 2. Advice on how to achieve a better game score, 3. Encouragement for the student to complete a task at a more difficult level, or 4. Answers to the student's questions. Types and examples of teacher feedback are listed in Table 1.

Dependent Variables

On-task behaviors. Academic engagement was the primary dependent variable and was measured in terms of on-task without inappropriate body movements (ONT-EX) and on-task with spontaneous body movement (ONT-SBM). ONT-EX was operationally defined as completing an assigned academic task as expected for at least six consecutive seconds of an interval of ten seconds. Under this status, the student sat still with eyes focusing on the material, with their hands holding the proper stationary. ONT-SBM was operationally defined as when a student was completing an assigned academic task with spontaneous and unrelated body movements for at least six consecutive seconds of an interval of ten seconds.

During ONT-SBM, the student's eyes were focusing on the material and doing the assignment, but they were also engaging in unrelated activities with other parts of their body, such as rocking motions, kneeling, or playing with a piece of stationary or gadget). Thus, this type of behavior could be conceptualized as a mid-point between ONT-EX and off-task behaviors. It may be the case this type of behavior triggers off-task behavior by weakening student's attentional focus (For mechanism of brain's attention networks and problems of attentive switch between multitasks, see Rothbart & Posner, 2015).

Off-task behaviors. Off-task behavior was separated into off-task motor activity (OFF-MA) and off-task passive behavior (OFF-PB). The operational definitions were adapted from the study by Vile and colleagues (2006). OFF-MA was defined as when the student had exhibited any motor activity that interrupted completion of the assigned academic task for at least six consecutive seconds of an interval of ten seconds. Examples included leaving their seat, playing with stationary/toys, or hiding under the desk. OFF-PB was defined as when a student was passively not doing the assigned task for at least six consecutive seconds of an interval of ten seconds. Examples included sleeping, day-dreaming, or staring at the window/door/wall/ceiling. We excluded off-task verbal behavior (e.g., talking to peers without teacher's permission; Vile Junod et al., 2006) because this behavior was not common in the observed settings.

Data Collection and Data Analysis

Behavioral data. Direct observations were conducted to assess academic engagement and on/off-task behavior during completion of academic assignments in the self-study room and small class setting (see below). In an observation, the student independently completed an assignment (10 minutes for Student A, 20 minutes for Student B) that matched his academic ability. While doing the assignments, they were allowed to skip items they felt unsure about.

The self-study room setting was a quiet small room (about $10m^2$) with a desk and chair. Before the observation, the researcher guided the student into the room and provided him with the academic material. The researcher made sure that the student understood the task requirements before they left the room. The student was required to complete the task on his own. The student was provided with sufficient stationary (e.g., pencil, ruler) for completing the academic task, and reminded to use the toilet room before starting the task.

The small class was set in a larger room (about $25m^2$). It was a mixed class of students of all grades, with 15 students who were seated in four rows by four columns. While the students were doing their academic assignments in the class, a teacher sat in the front of the class. A student having difficulty could raise their hand to inform the teacher – who would then assist them. The students were expected to stay in their seat and be quiet. Whispering, talking, or discussing with other students without teacher's permissions were not expected behaviors.

To minimize potential disturbance caused by observation in the self-study room setting, the student's performance was audio- and video-recorded. Later, a research assistant coded presence of target behaviors by watching the videos. Onsite observation was the primary method of observing the target behaviors in the small class setting. A research assistant sat in an aisle and remained unobtrusive to the observed student. Each observation cycle consisted of 10 seconds of observation followed by 2 seconds for recording. A "beep" sound recorded in a MP3 player with earphones was used to remind the observer of the 10 and 2 second intervals. In addition, video records were used as backup data in case there was a need to review past scenarios.

To calculate the percentage of ONT-EX, the number of occurrences of ONT-EX was divided by the total number of responses in a session and multiplied by 100. The percentage of ONT-SBM was calculated in the same way. The percentage of academic engagement (AET) was calculated by dividing the sum of the number of occurrences of ONT-EX and ONT-SBM by the total number of responses in a session and then multiplied by 100. To calculate the percentage of OFF-MA, the number of occurrences of OFF-MA was divided by the total number of responses in a session and then multiplied by 100. The percentage of OFF-PB was calculated in the same way. Visual inspection of the level and trend of the targeted behaviors was used to determine individual students' performance in each phase.

Effect size PAND/Phi was calculated to interpret change of each dependent variables by reflecting exact non-overlapping proportion between the baseline and other phases. PAND/Phi is an ES interpretation schemes that is suitable for indicating the magnitude of the training effect within single-case designs, especially for multiple baseline and multiple phases designs (Schneider, Goldstein, & Parker, 2008). Strengths of PAND/Phi to interpret outcomes of single-case designs include: (a) intuitive appeal and link to visual analysis, (b) data overlap is exact, and (c) no requirement for data normal distribution (Parker & Hagan-

Burke, 2007, p. 102). The procedure for calculating PAND/Phi within single subjects with a reverse design was provided by Schneider et al. (2008, pp. 155-157). According to Cohen (1992), small, medium, and large effect size of Chi-square for a two by two contingency table for a= 0.05 are 0.10, 0.30, and 0.50 respectively. In the present study, effect sizes were calculated within two conditions: within the reversal design, and from reversal to follow-up. The outcomes were used to determine effects of the neurocognitive training on each of the four behavioral variables (ONT-EX, ONT-SBM, OFF-MA, and OFF-PB) in the two conditions.

A graduate student with a major in Special Education was trained as the second observer. Inter-observer agreement was assessed on approximately 26% of observations of ONT-EX, ONT-SBM, OFF-MA, and OFF-PB of each participant. Kappa (*k*) indices were calculated for each observation to determine agreement for Student A (0.84, range= 0.66-1) and Student B (0.85, range= 0.66-1); for the self-study room setting (0.84, range= 0.66-1) and the small class setting (0.84, range= 0.66-1); and for ONT-EX (0.86, range= 0.70-0.97), ONT-SBM (0.83, range= 0.66-1), OFF-MA (0.84, range= 0.66-1), and OFF-PB (0.85, range= 0.66-1). Overall *k* averaged 0.84 (range= 0.66-1).

EEG data. The dry-sensor EEG recording device constantly measured EEG activity during training and was used to (a) control game-play during the state-control games, and (b) quantify attention level during the working memory and impulse-control games. The device consists of microchips, embedded firmware, a 10 mm active electrode and ear-clip reference ground electrode (ThinkGear, Neurosky, San Jose, California) contained within a headset (MindWave, Neurosky, USA). The EEG was recorded continuously from site Fp1 at 256 Hz and has been shown to be reliable and valid (Johnstone, Roodenrys, et al., 2012; Rogers et al., 2016). The device converted the raw signal from the time- to the frequency-domain via an Fast Fourier Transform, to calculate EEG power in the delta, theta, alpha, and beta frequency bands (see Johnstone, Roodenrys, et al., 2012 for more information). Based on conversion of the raw EEG signal to power in the delta, theta, alpha, and beta frequency bands via Fast Fourier Transform, proprietary algorithms then calculate values representing two independent psychological state dimensions of ‘‘attention’’ (low to high; highly correlated with power in the beta EEG band) and ‘‘relaxation’’ (tense to calm; highly correlated with power in the alpha EEG band). These measures are presented as a value between 0 and 100, enabling the provision of generalized feedback about ongoing brain activity in a form understood by children. This method provides a robust and universal index of ongoing EEG activity that does not require individual calibration. An additional index, termed “Zen”, was calculated in the software by averaging the attention and relaxation indices. The state indices were sent to the PC wirelessly via a Bluetooth connection. This EEG has been reported to be sensitive to psychological state variations that are relevant to the neurofeedback training goals contained within the state-control component of this training approach, i.e. high vs. low attention; high vs. low relaxation (Johnstone et al, 2012). Note that the EEG is used actively in the state-control training (see Training Session section), but passively during the impulse-control and working memory training where it simply monitors background attention level and categorizes attention into low/medium/high/very-high as a multiplier for game points achieved (x1/x2/x3/x4, respectively). The device constantly monitors electrode impedance and provides an ongoing numerical representation of its quality. The neurocognitive training software monitors this value and if sub-standard impedance occurs at any point (e.g. device is removed, or as a result of substantial head movement), the training game is paused until acceptable impedance in once again achieved.

Design and Procedures

A single-subject design with a reversal phase and a follow-up phase was applied to evaluate the effects of neurocognitive training on academic engagement and off-task behavior. Written consents were obtained from the parents and the manager of the after-school care center. During the pre-training phase, a two-hour information session about the software and EEG device was delivered to the students at the center. The first author served as the trainer, instructing students on how to play each game, and assisting them to play the games in a trail session.

The first baseline occurred over a 2-week period prior to commencement of the training, with behavioral data collected once every 2 days in each setting for each student. The first intervention phase occurred over a 2-week period during which each student completed 3 sessions of neurocognitive training each week; behavioral data were collected once every 2 days in each setting for each student. The second baseline occurred over a 2-week period prior to commencement of the training, with behavioral data collected once every 2 days in each setting for each student. The second intervention phase occurred over a 7-week period during which the student completed a session of training 3 times/week, with behavioral data collected 2 times/week in each setting for each student. Student B missed 2 sessions in the setting of small class because of family scheduling needs. The follow-up phase was conducted 2 weeks after termination of the second intervention phase, and occurred over a 2-week period in which observations were conducted 2 times/week in each setting for each student. During these research procedures, the students attended the center and received the service as normal.

Results

Results are described for academic engagement behaviors and off-task behaviors during completion of academic assignments across five phases (first baseline, first training phase, second baseline, second training phase, and follow-up) in two academic settings. Each variable was graphed independently by phase (see Figure 1, 2) and then interpreted by visual analysis for immediacy, level, and trend. Additionally, effect size PAND/Phi coefficient was calculated to determine the magnitude of change.

EEG data during the training

Average Focus, Relax, or Zen scores across the 25 training sessions are shown in Figure 1. Visual inspection of the data suggest some common trends for the three psychological states for both participants: 1) scores increased over the 25 training sessions, 2) scores were lowest in the first intervention phase, 3) there were large increases occurred during the first intervention phase, 4) scores reduced at sessions 7 and 8, after a period of no-training, and then started to increase again, and 5) the improvement tended to be more stable in the last 8-10 sessions (particularly for Relax and Zen). Other trends to note include that larger increases were observed for Focus than other states, and that compared with Student B, Student A had lower scores during the first four sessions but his improvements were larger and more sustained in the later sessions.

On-task behavior

The self-study room setting. Rates of targeted behaviors for each phase are shown in Figure 2. When completing their academic assignments during the first baseline, both students demonstrated low rates of ONT-EX and ONT-SBM. Student A's performances were lower. All of his ONT-EX and ONT-SBM sessions were below 50% and 10%, respectively. These resulted in a low level of academic engagement (AET) for Student A (mean = 29%, range = 15-52%) and a medium level of AET for Student B (mean = 70%, range = 46-94%). Once the neurocognitive training was introduced, immediate increases and positive growth in ONT-EX and AET were observed. For Student A, all rates of ONT-EX and AET were higher in this phase than the first baseline. Similar cases (except for the 6th session, see Figure 2) occurred in Student B.

During the second baseline, decreasing trends in ONT-EX and AET were observed. All rates of AET and most rates of ONT-EX (except for the 13th session for Student A and the 12th session for Student B, see Figure 2) were lower than in the first intervention phase. When the training was re-introduced, immediate and sustained improvements in ONT-EX and AET were noted. This resulted in medium levels of ONT-EX for Student A (mean = 82%, range = 51-97%) and Student B (mean = 80%, range = 59-97%), as well as high levels of AET for Student A (mean = 91%, range = 82-97%) and Student B (mean = 93%, range = 82-100%). Two weeks after termination of the training gains in ONT-EX were maintained for Student A (mean = 79%, range = 69-84%) and Student B (mean = 77%, range = 67-75%). Despite slight decreases, the rates were steadier in this follow-up phase than the second intervention phase. As for AET, larger and more sustained increases were found in Student B (mean = 96%, range = 89-100%) than Student A (mean = 83%, range = 76-92%).

A different pattern of changes was demonstrated in ONT-SBM. All rates were lower than 40% (except for the 5th session of Student B), with changes in this variable were minor throughout the phases. Decreasing trends were observed the in two intervention phases. In particular, an extremely low level (mean = 4%, range = 0-12%) occurred in the late 15 sessions for Student A.

Large effect sizes were obtained for ONT-EX within the reversal design for Student A (Phi = 0.79) and Student B (Phi = 0.67), as well as throughout the reversal design to follow-up for Student A (Phi = 0.80) and Student B (Phi = 0.69). Slightly larger effect sizes in the latter condition suggested maintenance of the positive effect 2-weeks after termination of the training. Small effect sizes in ONT-SBM for Student A were calculated within the reversal design (Phi = 0.04) and from the reversal design to follow-up (Phi = 0.10). Negative effect sizes in this variable for Student B were obtained within the reversal design (Phi = -0.10) and from the reversal design to follow-up (Phi = -0.02).

The small class setting. Rates of targeted behaviors for each phase are shown in Figure 3. When completing their academic assignments during the first baseline, both students demonstrated low rates of ONT-EX and ONT-SBM. In particular, ONT-EX for both students was lower than 30% (except that the 5^{th} session of Student A was 30%). This resulted in low rates of AET for Student A (mean = 22%, range = 9-35%) and Student B (mean = 44%, range = 40-48%). Once the neurocognitive training was introduced, increases in ONT-EX were demonstrated for both students. The rate of ONT-EX was three times (mean = 43%, range = 24-68%) and two times (mean = 47%, range = 32-63%) those observed in the first baseline for Student A and Student B, respectively. Further, AET values for all sessions were higher in this training phase than the first baseline for both students.

During the second baseline, decreasing trends in ONT-EX and AET were observed for both students. When the training was re-introduced, despite increases in the average percentage of ONT-EX for Student A (mean = 41%, range = 13-86%) and Student B (mean = 45%, range = 27-69%), slight decreasing trends with notable fluctuations were observed for the two variables. For AET, a slight decreasing trend was found for Student A (mean = 61%, range = 42-86%), whereas an increasing trend was found for Student B (mean = 63%, range = 41-75%). During the 2-week follow-up phase, increases with notable fluctuations in ONT-EX and AET were noted for both students.

A different pattern of changes was demonstrated in ONT-SBM. Most rates were lower than 40% (except for the 25th and 28th sessions for Student A and the 32nd session for Student B). More notable fluctuations were found in Student A. For both students, slight decreasing trends in the first intervention phase but increasing trends in the second intervention phase and 2-week follow-up were observed.

Medium effect sizes in ONT-EX were found for Student A within the reversal design (Phi = 0.30) and from the reversal design to the follow-up (Phi = 0.34), with large effect sizes found for Student B within the reversal design (Phi = 0.66) and from the reversal design to the follow-up (Phi = 0.69). As for ONT-SBM, there were small effect sizes within the reversal design for Student A (Phi = 0.20) and Student B (Phi = 0.18), as well as from the reversal design to the follow-up for Student A (Phi = 0.15) and Student B (Phi = 0.13).

In summary, these results suggest that neurocognitive training had immediate and positive effects on ONT-EX and AET for both students in two learning settings. This finding has been confirmed by effect size coefficients. However, these increasing trends that maintained throughout from the reversal design to the follow-up occurred in the self-study setting than the small class. Effectiveness of the training was not demonstrated for ONT-SBM in both settings.

Off-task Behavior

The self-study room setting. In regards to OFF-MA, each student performed quite differently. Student A showed a high rate (mean = 45%, range = 34-79%) during the first baseline, and once the training was introduced there were immediate and large decreases in this variable. After some increases in the rate of OFF-MA in the second baseline, immediate and sustained decreases were found after the training was re-introduced; a trend maintained in the 2-week follow-up. Most of the rates (except for the 19^{th} and 20^{th} sessions) during these phases were below 10%. Student B initially showed a low rate of OFF-MA (mean = 5%, range = 0-10%) and maintained low levels throughout the phases. After minor decreases during the first intervention phase, a slight increasing trend was found during the second baseline. Later, slight decreases maintained in the second intervention phase and 2-week follow-up.

As for OFF-PB, relatively high rates with notable fluctuations were found for Student A (mean = 26%, range = 14-44%) and Student B (mean = 25%, range = 6-48%). Immediate and large decreases were found after the training was introduced. Rates of this variable were at or below 10% for both students. After some increases during the second baseline, immediate and sustained decreases were observed for both students when the training was re-introduced. Most rates of this variable were below 5% (except for the 23rd session for Student A, and the 22nd and 27th sessions for Student B) for both students. However, such a trend was not maintained in the 2-week follow-up.

Large effect sizes in OFF-MA were calculated for Student A within the reversal design (Phi = 0.68) and from the reversal design to the follow-up (Phi = 0.70). Medium effect sizes were obtained for Student B within the reversal design (Phi = 0.34) and from the reversal design to the follow-up (Phi = 0.30). As for OFF-PB, large effect sizes were obtained within the reversal design for Student A (Phi = 0.79) and Student B (Phi = 0.67), as well as from the reversal design to follow-up for Student A (Phi = 0.60) and Student B (Phi = 0.69).

The small class setting. For OFF-MA, each student performed differently throughout the phases. Student A demonstrated a high rate of OFF-MA (mean = 47%, range = 18-65%) during the first baseline. When the training was introduced, despite decreases in the average percentage (mean = 31%, range = 20-37%), a slight increasing trend was observed for this variable. After slight increases in the second baseline, immediate and sustained decreases with notable fluctuations in OFF-MA were observed during the second intervention phase. Later, steadier improvements occurred in the 2-week follow-up. Student B initially showed a low rate of OFF-MA (mean = 6%, range = 1-12%) and maintained low levels throughout the phases. After minor increases in the first intervention phase, decreasing trends were observed throughout the second intervention phase (mean = 1%, range = 0-5%) and 2-week follow-up (mean = 1%, range = 0-3%).

Rates of OFF-PB also differed between the students. During the first baseline, Student A showed lower rates with larger fluctuations (mean = 28%, range = 12-67%), while the rates for Student B were higher and more stable (mean = 44%, range = 40-51%). After the training was implemented, sustained improvements were found in both students. Considerably lower averaged rates were found for Student A (mean = 3%, range = 0-7%) than Student B (mean = 24%, range = 16-29%) in the first intervention phase. During the second baseline, increasing trends were demonstrated for both students. After the training was re-introduced, a sustained decreasing trend was found in Student B (mean = 27%, range = 12-43%), whereas an increasing trend was observed in Student A (mean = 15%, range = 3-37%). These trends maintained in the 2-week follow-up. In particular, the average rate of Student A's OFF-PB in the follow-up phase (mean = 31%, range = 23-39%) was higher than in the first baseline.

Medium effect sizes were obtained for OFF-MA within the reversal design for Student A (Phi = 0.40) and Student B (Phi = 0.44), as well as for the reversal design to follow-up for Student A (Phi = 0.43) and Student B (Phi = 0.47). For OFF-PB, medium effect sizes were obtained for Student A within the reversal design (Phi = 0.30) and from the reversal design to the follow-up (Phi = 0.34). Larger effect sizes were obtained for Student B within the reversal design (Phi = 0.78) and from the reversal design to the follow-up (Phi = 0.79).

In summary, these results suggest that the neurocognitive training had immediate and negative effects on OFF-MA and OFF-PB in the two settings for both students. This finding has been confirmed by effect size coefficients. The decreasing trends from the reversal design to the follow-up were more likely to sustain in the self-study setting than the small class.

Intervention Fidelity

The computer-delivered training program allowed for a robust protocol. In order to complete a session, the students were required to complete assigned tasks one by one. This procedure resulted in warranted treatment fidelity and reliability. Furthermore, increased task difficulty levels in the last five compared to the first five training sessions (see Table 2) indicated that the students showed good compliance; i.e. they put in effort and improved at the training games

Discussion

Previous research has reported positive effects of neurocognitive training in AD/HD. However, previous studies (e.g., Johnstone et al., 2017) that reported improved behavior mostly relied on indirect source of evidence (e.g., parent or teacher report). The purpose of this study was to examine effects of neurocognitive training on specific academic behaviors in the self-study setting and small class setting. Through the use of withdrawn design, specific academic behaviors were directly observed and reported across phases in two children with AD/HD. Previous studies (Hart et al., 2011; Imeraj et al., 2013) indicate that children with AD/HD tend to perform inattentive or disruptive behaviors in contexts that require high self-regulation or lack adult supervision. Thus, we set up two contexts in the present study by selecting tasks with academic contents and requiring the students to complete tasks independently and silently. Informed by previous studies (Hart et al., 2011; Imeraj et al., 2013), it was assumed that the students in the present study would need to engage executive functions and/or self-regulative abilities to sustain attention and remain on-task. It is worth noting that the small class setting was more challenging to the students as they had to deal with potential interferences (e.g., inappropriate communication) from other students.

Overall, improvements in academic engagement and reductions in off-task behaviors were demonstrated during the training compared to baseline phases. In particular, both students demonstrated immediate and positive growths in ONT-EX and AET in the two settings. More sustained and post-training improvements were observed in the setting of self-study room. Despite of these outcomes, visual inspection of the trend in the diagram and calculation of effect size coefficient suggested that the training had limited or no effectiveness on ONT-SBM. The present study contributes to research supporting neurocognitive training as an effective treatment for children with AD/HD to improve their academic engagement in day-to-day school activities.

Substantial improvements in awareness and control of psychological states factors (Focus, Relax, and Zen) occurred during the first training phase, with reduced achievement (after 2 weeks of no training) followed by sustained improvements during the 2^{nd} training phase. “Early response” refers to trajectories of rapid symptom changes within the first half of the treatment (Linardon, Brennan, & de la Piedad Garcia, 2016). Early response is a favorable pattern in treatment as it has been reported to predict better outcomes at treatment termination and short-/long-term follow-ups (Barb, Siegle, Young, & Huppert, 2018; Kleinstäuber, Lambert, & Hiller, 2017). Ideally, our observed early response trajectory for the psychological states predicts (or generalizes) change of expected behavior in a similar way. Linking this pattern to changes in academic engagement behaviors lead to two interesting points for consideration.

Firstly, contextual differences may be an influential factor in generalization of training potency to expected behavior. Changes in ONT-EX and AET in the self-study room setting met the criteria for early change, and showed an increasing trend across training sessions. In contrast, changes in these variables in the small class setting did not show an initial increasing trend nor maintain improvement in later sessions. As for OFF-MA and OFF-PB, an ideal pattern might be 'early reduction with sustained decreases', which was in line with the pattern of psychological states. This expected pattern was observed in the self-study room (except for Student B's OFF-MA) but not the small class setting. Thus is seems that simple contexts (e.g., self-contained, with minimal distractors) are likely to facilitate the generalization from state control/regulation improvements to behavioral performance. In contrast, complicated contexts, such as small/whole classrooms, may contain factors that hinders this generalization. This finding is somewhat contrary to previous studies which have suggested that on-task behavior is more likely to occur in a small group setting than during independent silent work (Hart et al., 2011). In addition, the finding does not support that of Lauth et al. (2006) who found a higher level of off-task behavior during instructions with minimal teacher supervision. Indeed, convergence of EEG/state scores and observational outcomes implies that behavioral generalization from the training is more likely occur in simpler contexts. It is worthwhile for future studies to investigate the mechanism of generalizing effects of neurocognitive training to learning-related behavior.

The second consideration is about development of on-task behavior with spontaneous body movement (i.e., ONT-SBM), which did not meet the pattern of early response and was not congruent with the expected on-task behavior (i.e., ONT-EX). While a decreasing trend was found in the self-study room setting, an increasing trend in this behavior was observed in the small class setting. Beside of the potential influence of context difference, the trait of spontaneous body movement itself might play a mediating role during transfer from off-task behavior to on-task behavior. In the situation where on-task behavior was easy to implement, the training might facilitate changing on-task behavior with spontaneous activities to the desired on-task behavior. This possibly explained sustained decreases in this variable in the setting of self-study room. In another situation where on-task behavior was more difficult to exert (e.g., in the setting of small class due to external distractors), the training might facilitate changing off-task behaviors to on-task behavior with spontaneous activities. This possibly may explain the sustained increase of this behavior in the setting of small class.

Previous studies have reported that the rate of spontaneous activities (e.g., body movement, mind wandering) during sustained attention tasks are associated with inattentive symptoms (Frid, Lavner, & Rabinowitz, 2012; Seli, Smallwood, Cheyne, & Smilek, 2015). This does not seem to be the case in the small class setting in our study. When off-task behaviors declined, increasing trends in ONT-SBM were observed. This finding, thus, calls for investigation of the role that spontaneous activities play in shifting from off-task to on-task. To our knowledge, there is little research on this topic.

Despite the common improvement in academic behaviors, different improvement patterns in these variables were found between participants. While Student A demonstrated improvement with large effect sizes in ONT-EX, OFF-MA, and OFF-PB in the setting of self-study room, he only showed improvements with medium effect sizes for these variables in the small class setting. In contrast, Student B made similar improvements in both settings. Even though the same training protocol was implemented, non-treatment variables might be account for such discrepancies. Evaluative studies of behavioral treatments (e.g., cognitive-behavioral therapy, parent training, residential treatment) have reported that various pretreatment factors (e.g., contextual variables, comorbidity, readiness to change) influence outcomes for children with AD/HD (Beauchaine et al., 2015; den Dunnen, St. Pierre, Stewart, Johnson, Cook, & Leschied, 2012; Jarrett, 2013). Neurocognitive training has revealed its own arena of promising effectiveness, which is different from behavioral treatment nor stimulus medication (for a review, see Chacko et al., 2014). Thus, one direction for future research may be to explore pretreatment variables that enhance training potency. Coherently, training protocols need to be tailored to incorporate variable(s) for catering for children with a diversity of backgrounds.

While previous studies have shown some preferable outcomes after neurocognitive training, these studies often overlooked contextual factors. Here we examined the efficacy of neurocognitive training in differentiated instructional contexts. Taking effect size coefficient phi of each variable into account, more positive outcomes were found in the setting of self-study room than small class. This finding, although preliminary, suggests that future research may assess the extent to which learning context may affect training effectiveness. Implying from the results of the present study, it is likely that children are more capable of maintaining the training effects in contexts that are free from external distractions. A proposed solution of enhancing potency of neurocognitive training in varied learning contexts may incorporate behavioral strategies that are responsive to environmental variables (Chacko et al., 2014). However, substantial research need to be conducted to prove validity of this proposition.

In the present study the neurocognitive training was conducted with teacher feedback – this has not been the case in previous studies. Teacher feedback has been found to have powerful impacts on student performance. Hattie (2009) reviewed 23 meta-analyses and reported an overall effect size *d* = 0.73 for teacher feedback on student performance, with the most effective form of feedback being the provision of cues or reinforcement. Further, providing positive and specific feedback about student's performance is a recommended instructional strategy for children with AD/HD (DuPaul, Weyandt, & Janusis, 2011; Fowler, 2010). Teacher feedback in conjunction with other techniques/interventions is effective in decreasing inappropriate classroom behavior (Price, Martella, Marchand-Martella, & Cleanthous, 2002) and increasing on-task behavior (Jurbergs, Palcic, & Kelley, 2010) for children with AD/HD in previous studies. Thus, the third direction for exploration is assessing the relative contribution of adult feedback on the effects of neurocognitive training. It would be interesting to examine whether or how the training outcomes may be enhanced by collaborating with behavioral/instructional strategies such as teacher feedback.

Limitations

There are several limitations that must be considered when interpreting the results. Firstly, this study did not involve children with the predominantly hyperactive-impulsive presentation (AD/HD-HI). Additionally, it did not involve participants with comorbid disorders. Although other disorders (e.g., oppositional defiant disorder, anxiety disorder) may co-occur with AD/HD (American Psychiatric Association, 2013), manifestation of comorbidity disorders may be more complicated and is beyond research interest of the present study. Therefore, findings of this study may have a limited implication for educational interventions for the subtype of AD/HD-HI or AD/HD with comorbidities.

Second, the participants were randomly drawn from a pool that consisted of students with AD/HD with learning difficulties in mainstream classrooms. In this situation, some students in the pool might have low aptitude in learning, for example, Student A in the present study (relatively low IQ). Moreover, possible co-morbid diagnoses in categories such as intellectual disability or learning disability were not considered. It is worthwhile to collect more specific case studies to report the progress and effectiveness of neurocognitive training on this subgroup.

Third, although gender difference was not a research interest of the present study, no female participants were involved. Considering potential differences of the training outcomes between female and male children, findings form this study may have a limited implication for girls with AD/HD. It is worthwhile for future studies to include female participants.

Fourth, the training was conducted after school (between 3 to 5pm). Although the participants were given a break and food before each session, they might still feel tired after a whole day of school. This issue might affect the training outcomes. Nevertheless, this situation represented somewhat the reality of conducting the training in school context.

School administrators may consider achieving academic teaching plans as a priority over providing extra-curricular training.

Fifth, although the present study was designed to examine a two-week follow-up phase, to assess the maintenance of training outcomes, the findings may have a limited implication for sustained real-world improvement. Future studies may adopt a longer follow-up phase to determine the sustained improvements. Fourth, this study was a preliminary study reporting effects of neurocognitive training on academic engagement in real-life settings. Given that a small number of participants was used, it is worthwhile for future studies to adopt designs with large sample sizes (e.g., blinded treatment-control design; Lofthouse et al., 2012)

Conclusion

While an emerging body of research has assessed behavioral outcomes of neurocognitive training in children with AD/HD, most of those studies relied on adults' report of children's behavior or clinically-based data (Chacko et al., 2014; Rapport et al., 2013). This multiple case-study extended the literature by evaluating the efficacy of neurocognitive training on academic engagement in real-life educational contexts through using direct observation. These findings support using this treatment for improving academic engagement in children with AD/HD. Whether or not contextual differences, non-treatment variables (e.g., children's motivation), or adult's feedback, may affect treatment efficacy warrants future research.

References

American Psychiatric Association. (2013). Diagnostic and Statistical Manual of Mental Disorders: Dsm-5. Arlington, VA: American Psychiatric Association.

Barb, S., Siegle, G., Young, K., & Huppert, T. (2018). Augmenting Cbt with Real-Time Fmri Amygdala Neurofeedback Training Increases Early Response to Therapy. *BIOLOGICAL PSYCHIATRY, 83*(9), S188-S188.

Barry, R. J., Clarke, A. R., & Johnstone, S. J. (2003). A Review of Electrophysiology in Attention-Deficit/Hyperactivity Disorder: I. Qualitative and Quantitative Electroencephalography. *Clinical Neurophysiology, 114*, 171-183. doi:10.1016/S1388-2457(02)00362-0

Beauchaine, T. P., Neuhaus, E., Gatzke-Kopp, L. M., Reid, M. J., Chipman, J., Olliges, A., . . . Webster-Stratton, C. (2015). Electrodermal Responding Predicts Responses to, and May Be Altered by, Preschool Intervention for Adhd. *Journal of Consulting & Clinical Psychology, 83*(2), 293-303. doi:10.1037/a0038405

Chacko, A., Kofler, M., & Jarrett, M. (2014). Improving Outcomes for Youth with Adhd: A Conceptual Framework for Combined Neurocognitive and Skill-Based Treatment Approaches. *Clinical Child & Family Psychology Review, 17*(4), 368-384. doi:10.1007/s10567-014-0171-5

Cohen, J. (1992). A Power Primer. *Psychological Bulletin, 112*(1), 155-159. doi:10.1037/0033-2909.112.1.155

Cortese, S., Ferrin, M., Brandeis, D., Holtmann, M., Aggensteiner, P., Daley, D., . . . Sonuga-Barke, E. J. S. (2016). Neurofeedback for Attention-Deficit/Hyperactivity Disorder: Meta-Analysis of Clinical and Neuropsychological Outcomes from Randomized Controlled Trials. *Journal of the American Academy of Child & Adolescent Psychiatry, 55*(6), 444-455. doi:10.1016/j.jaac.2016.03.007

den Dunnen, W., St. Pierre, J., Stewart, S. L., Johnson, A., Cook, S., & Leschied, A. W. (2012). Predicting Residential Treatment Outcomes for Emotionally and Behaviorally Disordered Youth: The Role of Pretreatment Factors. *Residential Treatment for Children & Youth, 29*(1), 13-31.

DuPaul, G. J., & Joshua, M. L. (2015). Educational Impairements in Children with Adhd. In R. A. Barkley (Ed.), *Attention-Deficit Hyperactivity Disorder: A Handbook for Diagnosis* *and Treatment* (4th ed., pp. 311-349). New York: The Guilford Press.

DuPaul, G. J., Weyandt, L. L., & Janusis, G. M. (2011). Adhd in the Classroom: Effective Intervention Strategies. *Theory Into Practice, 50*(1), 35-42.

Egeland, J., Johansen, S. N., & Ueland, T. (2009). Differentiating between Adhd Sub-Types on Ccpt Measures of Sustained Attention and Vigilance. *Scandinavian Journal of Psychology, 50*(4), 347-354. doi:10.1111/j.1467-9450.2009.00717.x

Fowler, M. (2010). Increasing on-Task Performance for Students with Adhd. *Education Digest: Essential Readings Condensed for Quick Review, 76*(2), 44-50.

Frid, A., Lavner, Y., & Rabinowitz, I. (2012). *Analysis of Finger Tapping Parameters in People with Adhd*. Paper presented at the IEEE 27th Convention of Electrical and Electronics Engineers, Israel. Conference retrieved from http://ezproxy.uow.edu.au/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=edseee&AN=edseee.6377064&site=eds-live

Hart, K. C., Massetti, G. M., Fabiano, G. A., Pariseau, M. E., & Pelham, W. E., Jr. (2011). Impact of Group Size on Classroom on-Task Behavior and Work Productivity in Children with Adhd. *Journal of Emotional and Behavioral Disorders, 19*(1), 55-64.

Hattie, J. (2009). *Visible Learning : A Synthesis of over 800 Meta-Analyses Relating to Achievement* London : Routledge.

Hodgson, K., Hutchinson, A. D., & Denson, L. (2014). Nonpharmacological Treatments for Adhd: A Meta-Analytic Review. *Journal of attention disorders, 18*(4), 275-282. doi:10.1177/1087054712444732

Imeraj, L., Antrop, I., Sonuga-Barke, E., Deboutte, D., Deschepper, E., Bal, S., & Roeyers, H. (2013). The Impact of Instructional Context on Classroom on-Task Behavior: A Matched Comparison of Children with Adhd and Non-Adhd Classmates. *Journal of School Psychology, 51*, 487-498. doi:10.1016/j.jsp.2013.05.004

Jarrett, M. A. (2013). Treatment of Comorbid Attention-Deficit/Hyperactivity Disorder and Anxiety in Children: Processes of Change. *Psychological Assessment, 25*(2), 545-5558. doi:10.1037/a0031749

Jiang, H., & Johnstone, S. J. (2015). A Preliminary Multiple Case Report of Neurocognitive Training for Children with Ad/Hd in China. *SAGE Open, 5*(2). doi:10.1177/2158244015586811

Johnstone, S. J. (2013). Computer Gaming and Adhd: Potential Positive Influences on Behavior. *IEEE Technology & Society Magazine, 32*(1), 20-22. doi:10.1109/mts.2013.2249355

Johnstone, S. J., Blackman, R., & Bruggemann, J. M. (2012). Eeg from a Single-Channel Dry-Sensor Recording Device. *Clinical EEG and Neuroscience, 43*(2), 112-120. doi:10.1177/1550059411435857

Johnstone, S. J., Roodenrys, S., Blackman, R., Johnston, E., Loveday, K., Mantz, S., & Barratt, M. F. (2012). Neurocognitive Training for Children with and without Ad/Hd. *Attention Deficit and Hyperactivity Disorders, 4*(1), 11-23. doi:10.1007/s12402-011-0069-8

Johnstone, S. J., Roodenrys, S., Phillips, E. A., Watt, A. J., & Mantz, S. (2010). A Pilot Study of Combined Working Memory and Inhibition Training for Children with Ad/Hd. *Attention Deficit and Hyperactivity Disorders, 2*(1), 31-42. doi:10.1007/s12402-009-0017-z

Johnstone, S. J., Roodenrys, S. J., Johnson, K., Bonfield, R., & Bennett, S. J. (2017). Game-Based Combined Cognitive and Neurofeedback Training Using Focus Pocus Reduces Symptom Severity in Children with Diagnosed Ad/Hd and Subclinical Ad/Hd. *International Journal of Psychophysiology, 116*, 32-44. doi:10.1016/j.ijpsycho.2017.02.015

Jurbergs, N., Palcic, J. L., & Kelley, M. L. (2010). Daily Behavior Report Cards with and without Home-Based Consequences: Improving Classroom Behavior in Low Income, African American Children with Adhd. *Child & Family Behavior Therapy, 32*(3), 177-195.

Kleinstäuber, M., Lambert, M. J., & Hiller, W. (2017). Early Response in Cognitive-Behavior Therapy for Syndromes of Medically Unexplained Symptoms. *BMC Psychiatry, 17*(1), 195-195. doi:10.1186/s12888-017-1351-x

Kofler, M. J., Rapport, M. D., & Alderson, R. M. (2008). Quantifying Adhd Classroom Inattentiveness, Its Moderators, and Variability: A Meta-Analytic Review. *Journal Of Child Psychology And Psychiatry, And Allied Disciplines, 49*(1), 59-69. doi:10.1111/j.1469-7610.2007.01809.x

Langberg, J. M., Molina, B. S. G., Arnold, L. E., Epstein, J. N., Altaye, M., Hinshaw, S. P., . . . Hechtman, L. (2011). Patterns and Predictors of Adolescent Academic Achievement and Performance in a Sample of Children with Attention-Deficit/Hyperactivity Disorder. *Journal of Clinical Child and Adolescent Psychology, 40*(4), 519-531.

Lauth, G. W., Heubeck, B. G., & Mackowiak, K. (2006). Observation of Children with Attention-Deficit Hyperactivity (Adhd) Problems in Three Natural Classroom Contexts. *British Journal of Educational Psychology, 76*(2), 385-404.

doi:10.1348/000709905X43797

Linardon, J., Brennan, L., & de la Piedad Garcia, X. (2016). Rapid Response to Eating Disorder Treatment: A Systematic Review and Meta-Analysis. *International Journal of Eating Disorders, 49*(10), 905-919. doi:10.1002/eat.22595

Liu, C.-Y., Huang, W.-L., Kao, W.-C., & Gau, S. S.-F. (2017). Influence of Disruptive Behavior Disorders on Academic Performance and School Functions of Youths with Attention-Deficit/Hyperactivity Disorder. *Child Psychiatry and Human Development*. doi:10.1007/s10578-017-0710-7

Lofthouse, N., Arnold, L. E., Hersch, S., Hurt, E., & DeBeus, R. (2012). A Review of Neurofeedback Treatment for Pediatric Adhd. *Journal of Attention Disorders, 16*(5), 351-372. doi:10.1177/1087054711427530

Mayer, K., Wyckoff, S. N., & Strehl, U. (2013). One Size Fits All? Slow Cortical Potentials Neurofeedback: A Review. *Journal of attention disorders, 17*(5), 393-409. doi:10.1177/1087054712468053

Parker, C., Whear, R., Ukoumunne, O. C., Bethel, A., Thompson-Coon, J., Stein, K., & Ford, T. (2015). School Exclusion in Children with Psychiatric Disorder or Impairing Psychopathology: A Systematic Review. *Emotional & Behavioural Difficulties, 20*(3), 229-251. doi:10.1080/13632752.2014.945741

Parker, R., & Hagan-Burke, S. (2007). Useful Effect Size Interpretations for Single Case Research. *Behavior Therapy, 38*(1), 95-105. doi:10.1016/j.beth.2006.05.002

Pingault, J.-B., Côté, S. M., Vitaro, F., Falissard, B., Genolini, C., & Tremblay, R. E. (2014). The Developmental Course of Childhood Inattention Symptoms Uniquely Predicts Educational Attainment: A 16-Year Longitudinal Study. *Psychiatry Research, 219*(3), 707-709. doi:https://doi.org/10.1016/j.psychres.2014.06.022

Price, A. T., Martella, R. C., Marchand-Martella, N. E., & Cleanthous, C. C. (2002). A Comparison of Immediate Feedback Delivered Via an Fm Headset Versus Delayed Feedback on the Inappropriate Verbalizations of a Student with Adhd. *Education and Treatment of Children, 25*(2), 159-171.

Rapport, M. D., Kofler, M. J., Alderson, R. M., Timko, T. M., Jr., & DuPaul, G. J. (2009). Variability of Attention Processes in Adhd: Observations from the Classroom. *Journal of Attention Disorders, 12*(6), 563-573.

Rapport, M. D., Orban, S. A., Kofler, M. J., & Friedman, L. M. (2013). Do Programs Designed to Train Working Memory, Other Executive Functions, and Attention Benefit Children with Adhd? A Meta-Analytic Review of Cognitive, Academic, and Behavioral Outcomes. *Clinical Psychology Review, 33*(8), 1237-1252. doi:https://doi.org/10.1016/j.cpr.2013.08.005

Rapport, M. D., Orban, S. A., Kofler, M. J., Friedman, L. M., & Bolden, J. (2015). Executive Function Training for Children with Adhd. In R. A. Barkley (Ed.), *Attention-Deficit Hyperactivity Disorder: A Handbook for Diagnosis and Treatment* (4th ed., pp. 1131-1171). New York: The Guilford Press.

Rapport, M. D., Scanlan, S. W., & Denney, C. B. (1999). Attention-Deficit/Hyperactivity Disorder and Scholastic Achievement: A Model of Dual Developmental Pathways. *Journal Of Child Psychology And Psychiatry, And Allied Disciplines, 40*(8), 1169-1183.

Rodriguez, A., Järvelin, M.-R., Obel, C., Taanila, A., Miettunen, J., Moilanen, I., . . . Olsen, J. (2007). Do Inattention and Hyperactivity Symptoms Equal Scholastic Impairment? Evidence from Three European Cohorts. *BMC Public Health, 7*, 327-327.

Rogers, J. M., Aminov, A., Wilson, P. H., & Johnstone, S. J. (2016). Retest Reliability of a Single-Channel, Wireless Eeg Device. *International Journal of Psychophysiology, 106*, 87-96.

Rogers, M., & Tannock, R. (2013). Are Classrooms Meeting the Basic Psychological Needs of Children with Adhd Symptoms? A Self-Determination Theory Perspective. *Journal Of Attention Disorders*.

Rothbart, M. K., & Posner, M. I. (2015). The Developing Brain in a Multitasking World. *Developmental Review, 35*(Supplement C), 42-63. doi:https://doi.org/10.1016/j.dr.2014.12.006

Sarver, D. E., Rapport, M. D., Kofler, M. J., Raiker, J. S., & Friedman, L. M. (2015). Hyperactivity in Attention-Deficit/Hyperactivity Disorder (Adhd): Impairing Deficit or Compensatory Behavior? *Journal Of Abnormal Child Psychology, 43*(7), 1219-1232. doi:10.1007/s10802-015-0011-1

Schneider, N., Goldstein, H., & Parker, R. (2008). Social Skills Interventions for Children with Autism: A Meta-Analytic Application of Percentage of All Non-Overlapping Data (Pand). *Evidence-Based Communication Assessment & Intervention, 2*(3), 152-162. doi:10.1080/17489530802505396

Seli, P., Smallwood, J., Cheyne, J. A., & Smilek, D. (2015). On the Relation of Mind Wandering and Adhd Symptomatology. *Psychonomic Bulletin & Review, 22*(3), 629-636. doi:10.3758/s13423-014-0793-0

Sergeant, J. A. (2005a). The Dynamic Developmental Theory of Adhd: Reflections from a Cognitive Energetic Model Standpoint. *Behavioral and Brain Sciences, 28*(3), 442-443. doi:10.1017/s0140525x05380071

Sergeant, J. A. (2005b). Modeling Attention-Deficit/Hyperactivity Disorder: A Critical Appraisal of the Cognitive-Energetic Model. *Biological Psychiatry, 57*(11), 1248-1255. doi:10.1016/j.biopsych.2004.09.010

Steiner, N. J., Frenette, E. C., Rene, K. M., Brennan, R. T., & Perrin, E. C. (2014). In-School Neurofeedback Training for Adhd: Sustained Improvements from a Randomized Control Trial. *Pediatrics, 133*(3), 483-492. doi:10.1542/peds.2013-2059

Steiner, N. J., Sheldrick, R. C., Gotthelf, D., & Perrin, E. C. (2011). Computer-Based Attention Training in the Schools for Children with Attention Deficit/Hyperactivity Disorder: A Preliminary Trial. *Clinical Pediatrics, 50*(7), 615-622. doi:10.1177/0009922810397887

Swanson, J. M., Kraemer, H. C., Hinshaw, S. P., Arnold, L. E., Conners, C. K., Abikoff, H. B., . . . Wu, M. (2001). Clinical Relevance of the Primary Findings of the Mta: Success Rates Based on Severity of Adhd and Odd Symptoms at the End of Treatment. *Journal Of The American Academy Of Child And Adolescent Psychiatry, 40*(2), 168-179.

Vile Junod, R. E., DuPaul, G. J., Jitendra, A. K., Volpe, R. J., & Cleary, K. S. (2006). Classroom Observations of Students with and without Adhd: Differences across Types of Engagement. *Journal of School Psychology, 44*, 87-104. doi:10.1016/j.jsp.2005.12.004

Wechsler, D. (2003). *Wechsler Intelligence Scale for Children-Fourth Edition*. San Antonio, TX: Psychological Corporation.