The training effect of concentrative coordination exercise on the executive functions and handwriting performance of children with ADHD

Introduction

For handwriting problems in ADHD, detecting executive function deficits through handwriting features is important because the executive function components, such as inhibition, emotional control, working memory, and monitoring, are required for varied daily functions besides handwriting (Rosenblum, 2018).Executive function is defined as the cognitive abilities that maintain an appropriate problem-solving set to attain a future goal and is thought to be highly relevant for daily life activities, appropriate behavior, and academic and social functions. Research consistently documents that ADHD is characterized by deficits in executive function with ADHD children performing more poorly on a range of executive function tasks relative to control participants (Shallice et al., 2002). The research results of Elosúa, Del Olmo, and Contreras (2017) supported the existence of alterations in the executive functions of children with ADHD, although not all of them would be affected, with relevant differentiation in the specific performance of each executive function (divided attention, updating, attentional shifting, and inhibition). Their study supported the hypothesis that executive function deficits are an important component of ADHD neuropsychology, although they are insufficient to fully explain its symptomatology.

There are many different forms of therapy used for children with ADHD. The most widespread one is the medicinal treatment using the drug Ritalin, which can be effective in certain cases as an immediate remedy. However, the comparison with healthy children revealed considerable deficits regarding vigilance, divided attention, flexibility, and selective attention (focused attention and integration of sensory information) in children with ADHD on methylphenidate (Tucha et al., 2006). The kinematic analysis of handwriting movements of the study by Tucha and Lange (2001) revealed that boys with ADHD on methylphenidate displayed more inversions in the direction of velocity and acceleration profiles as well as lower maximum velocities and accelerations following the withdrawal of the drug. These findings indicate that on methylphenidate, handwriting movements of boys with ADHD are less fluent than off methylphenidate. The administration of methylphenidate alone is insufficient in the treatment of children with ADHD. Children with ADHD may benefit from instructions on how to best use their improved attentional capacities focusing on automaticity and smoothness of movements (Lange, Tucha, Walitza, Gerlach, Linder & Tucha, 2007).

It is therefore important to look for therapeutic approaches to improve and use attentional capacities. In research with modified table tennis task to study gaze pursuit and arms control of adolescent males with ADHD, Vickers, Rodrigues & Brown (2002) found a dissociation in processing visual information of short and long duration. They postulated that adolescents with ADHD are drawn to fast-paced tasks while avoiding those that require concentration and focus over extended periods. They concluded that the core deficit of ADHD is a deficit in processing long-duration information, and suggested creating opportunities for ADHD children to be involved in long-duration tasks that require concentration and focus over time. They proposed long-duration visuomotor activities that promote the development of more extensive neural networks that may facilitate the development of the short- and long-lived visuomotor systems. Table tennis comprised of both short- and long-lived visuomotor components suggested a training paradigm beneficial for such facilitations.

Tsai (2009) used ecological intervention to investigate the efficacy of table-tennis training on treating problems with attentional networks as well as a motor disorder in children with developmental coordination disorder. Table-tennis training resulted in significant improvement of cognitive and motor functions for children with developmental coordination disorder (DCD). Pan et al. (2019) also revealed the therapeutic effect of table tennis exercise on motor skills and executive functions in children with ADHD. They found that the table tennis exercise group scored significantly higher in the locomotor as well as object-control skills and executive functions compared with the ADHD non-training group. The results of these clinical studies may imply that training in timing, sequencing, and coordination training may be helpful for children with ADHD. Children with ADHD may benefit from table tennis exercise with the incorporation of concentrative training in instructions on how to best use their improved attentional capacities in school classes. Also, table tennis exercise includes the training in eye-tracking and eye-hand coordination which is important in the acquisition of fluent graphomotor skills.

In recent decades, active video gaming (exergame) has been emerging as a trend in leisure, fitness, education, and health sectors. Exergaming requires bodily movements to simulate an active gaming experience to function as a form of physical activity. It helps to combine physical and cognitive training in a gamified fashion, ensuring motivation, diversity, and adaptivity. A light and sound speed-based exergame has been used as an intervention program for children with autism spectrum disorder (Hilton et al., 2014). They found significant improvement in the reaction speed and executive function areas of working memory and metacognition and the motor area of strength and agility. Recent studies by Benzing and Schmidt (2019) also revealed that exergaming benefited executive functions and motor abilities in children with ADHD. The above findings suggest that the use of exergaming has the potential to be an intervention for attention and concentration training.

This study aimed to determine whether the coordination training and the necessary concentration of visual information in table tennis tasks can improve the executive functions and graphomotor performances which are needed in daily and school activities. There were two intervention programs used in the present study: the onsite and exergaming table tennis. A randomized control study was performed to test the intervention effect on the outcome measures of executive functions and handwriting performance. Through a two-way block design, this controlled study can identify the intervention effect and determine the difference between the two programs.

Methodology

Subject recruitments

This study was designed to test the efficacy of intervention programs on the executive functions and handwriting performances of ADHD. The identification of a handwriting problem will be confirmed by the administration of the Chinese Handwriting Evaluation Form (CHEF). According to the test manual, the cut-off criterion for the identification of handwriting deficit is two or more of the six dimensions with a median larger than, or equal to, 3 Chang (Chang & Yu, 2005). It is used to confirm the handwriting deficit and to measure the improvement across the intervention program.

Children will be excluded from this study when they report a history of any medical, neurological, or pervasive developmental disorders, intellectual disability, oncological, musculoskeletal, sensory (hearing, vision), or skin disorders. Children with IQ score < 80 or taking any medication other than methylphenidate will be excluded from this study. Sixty children (from grade 1 to grade 6) who meet the criteria of DSM-V for ADHD and confirmed with handwriting deficits will be recruited. The children will then be randomly allocated into the onsite, exergame (Wii) table tennis, or control groups. All of the referrals of ADHD will be confirmed by pediatric psychiatrists.

Table Tennis Training protocol

The training interventions will be performed in a sequence of increasing complexity. Each training session includes a warm-up, the main part of table tennis training, playing a table tennis game with a partner, and cooling down at the end. The main part of table tennis training is provided either by the coach or a ball-projection machine. The child does not play with the machine until he can successfully return the serve of the coach with a minimum ratio of 0.6 (about the fourth week). There will be 5 main components provided by the coach over the whole training session: (a) serving, (b) bouncing, (c) smashing, (d) driving, and (e) footwork. Each skill begins with a simple movement and then progresses to more complex variations. In the main program, children will be required to spend as much training time as possible on the table hitting the ball. After the main training part, the comprehensive practice is performed by playing a game with a partner. It also includes games but keep a ratio of at least 70% training to 30% games. After four weeks of training, more task-specific training will be added to the main program. The program is structured to achieve a particular type of training that is expected to relate to executive attention in general, with a special focus on short- and long-lived visuomotor control for the ADHD group.

After the child could successfully return the serve of the coach with a minimum ratio of 0.6, the one-half training of the main program will be conducted by a ball-projection machine. The first part is a modified protocol originally designed to improve executive attention, response, and the inhibitory control of the child’s cognitive and motor skills (Tsai, 2009). First, the machine provides training, continuously hitting back a ball that is delivered at the same speed and from the same direction by the ball-projection machine. Secondly, for inhibitory control and executive attention, the ball-projection machine serves yellow and white balls randomly. It requires that only the yellow balls are to be hit, and thus that the children should inhibit movement programming when a white one is projected. For the progression of task complexity, balls are first projected from a specified direction and then project randomly from uncertain directions and at uncertain times to hinder any prediction of what will happen next. Feedback will be provided by the coach to the child after each stroke for encouragement.

The second part is a modified protocol originally designed to study gaze pursuit and arms control of adolescent males with ADHD (Vickers et al., 2002). For visuomotor training, Figure 1 shows a regular table tennis table fitted with target areas, ball-projection machines, and participants. For a right-hander, the task set-up in (A) and (B) requires the return of a table tennis ball to either the left or right side of the table using a forehand drive. The machine with a rotational head can serve to both sides. The rotation of the projected head cues the direction of serve. The color of table tennis cues the required direction of rebound: orange for the same side and white for the opposite side. As shown in Figure 1, there are four modes for visuomotor training. Before the conduction of the experiment, three consecutive training sessions will be given to each participant. The experiment does not start until the participant could successfully return 50% of the serves from the machine.

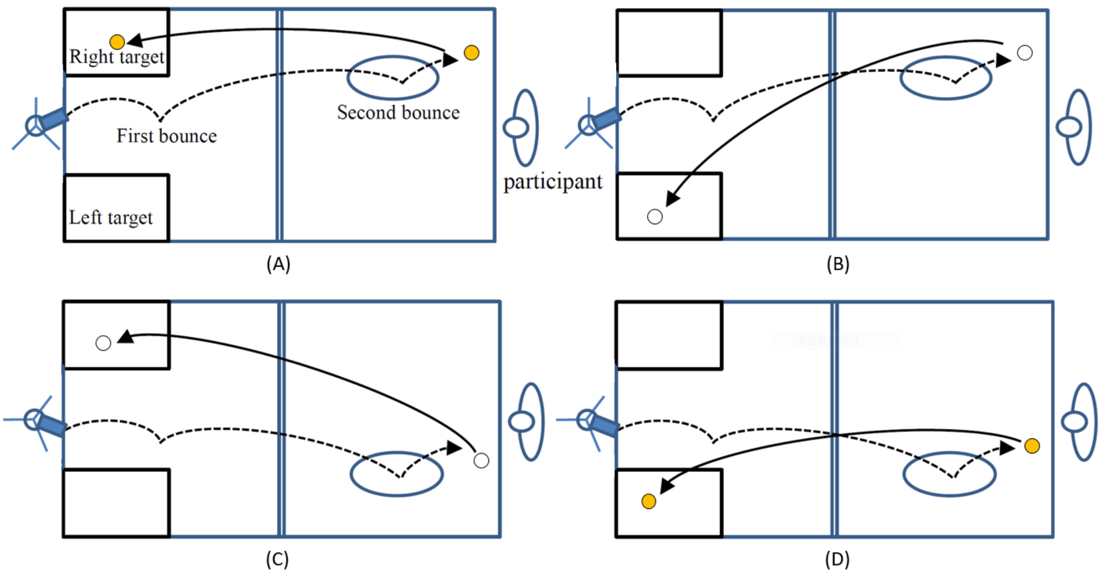

Figure 1. Four basic training modes: The table tennis table fitted ball-projection machine and cue by ball colors. In (A) and (C), orange balls cue to return to the same side. In (B) and (D), white balls cue to return to the opposite side.

Table tennis exergame training principles

Since the Nintendo Wii Sport will be designed as a simulated way to exercise in the comfort of the player's setting, this study used Nintendo Wii Sport to provide coordination exercise and train the concentration of the children with ADHD. The exergame will be displayed on a TV set with a 55-inch LCD panel (Chimei, TL-55LV700D, 1920*1080). The appealing cell-shaded graphics and endearing music, on top of the super-fun gameplay, have children playing with abundant visual and sensory stimulation. In this study, the trainer first establishes the participant's exergame play proficiency. Players who had not previously used the handheld control panel will be given instructions and several minutes of practice until they demonstrate proficiency in using the directional buttons and the button for "firing" required for the target game. This procedure will be repeated before the administration of the adventure exergame to ensure that all players demonstrated proficiency in the appropriate use of the simulated racket. The training game can be either single or versus mode. For a more sophisticated and vivid experience, a minigame can be chosen to play in advance. In Versus mode, the subject and an opponent can play against each other to see who is the better table tennis player. And if Single and Versus modes are well-practiced, the training program includes three minigames: Target Table Tennis, Thrilling Table Tennis, and Matching Table Tennis. All three minigames will be included in every training session for even periods.

Study design

There are three stages in the experimental procedure: (1) pre-test, (2) intervention, and (3) post-test. During the intervention, children with ADHD in the intervention groups will be regularly trained in a series of 60-min sessions conducted three times a week for twelve weeks (36 sessions in total). The outcome measures included neuropsychological tests (Stroop test and Wisconsin Card Sorting Test), and graphomotor function tests (handwriting automation, movement, and performance tests).

Differences in the outcome measures, after 12 weeks, across the onsite table tennis and exergame, and control groups (matched for age and grade) will be analyzed by comparing the effects of therapeutic exercise program and exergame program in a repeated measures design (before and after intervention), on the dependent variables: scores of neuropsychological tests and handwriting performance. Each pupil will perform each of the writing tasks according to a randomized block design. The data of the control group will be also collected as a basis of comparison. Four weeks before this study and in the period of study, all the participants stop any of the intervention programs, such as occupational or physical therapy except medication and exercises provided by this study. The medication of Ritalin will be matched in the group assignment.

Neuropsychological tests for executive function

(1) The Stroop test

The Stroop Test is a color-naming task developed by Stroop (1935). It tests the effect related to the ability of most people to read words more quickly and automatically than they can name colors. The Stroop test is an outcome of mental (attentional) vitality and flexibility. If a word is displayed in a color different from the color it names; for example, if the word green is written in blue ink, then we have a hard time noticing the blue ink. In this instance, even when asked to name the color of the ink, we tend to say the name the word represents. During the Stroop test, the child is instructed to identify the color of ink verbally as quickly as possible based on trials listed in each condition. The Stroop test includes three conditions: Stroop Word, Stroop Color, and Stroop Color-Word. The Stroop Word condition involves 50 trials with color names (i.e., blue, red, green) written in black ink. The Stroop Color condition involves 50 trials with color names in same-colored rectangles. Stroop Color-Word involves 50 trials with color names printed in different color ink (i.e., “GREEN” printed in red ink). Trials in each condition will be displayed on a sheet of paper, and children were asked to name the trials from top to bottom (10 trials) and left to the right column (5 columns). The Stroop test was chosen because of evidence that it measures executive functions and is sensitive to the effects of acute exercise (Sibley, Etnier, & Le Masurier, 2006).

(2) Wisconsin Card Sorting Test (WCST)

The Wisconsin Card Sorting Test (WCST) is a neuropsychological assessment instrument widely used for psychiatric and neurological patients for assessing higher-order cognitive functions that are related to the brain’s frontal lobes. Successful completion of the WCST requires multiple cognitive operations, which include: strategic planning, organized searching, the application of external feedback to shift mental sets, and the inhibition of impulsive responses (Greve, Stickle, Love, Bianchini, & Stanford, 2005). These higher-order cognitive functions are called executive functions, and failure on the WCST performance implies executive dysfunction.

The WCST consists of 4 stimulus cards and 2 identical decks of 64 response cards (a total of 128 response cards). The response cards display figures of varying forms (crosses, circles, triangles, or stars), colors (red, blue, yellow, or green), and numbers of figures (1, 2, 3, or 4). The stimulus cards are always presented from the participant’s perspective in a standard left-to-right order: 1 red triangle, 2 green stars, 3 yellow crosses, and 4 blue circles. Initially, a series of stimulus cards are presented to the participant. The participant is told to match the cards, but not how to match; however, he or she is told whether a particular match is right or wrong.

Instead of using paper cards, this study used computerized versions (Microsoft Windows-compatible version 4.0.) which have the advantage of automatically scoring the test. The test takes approximately 12-20 minutes to carry out and generates psychometric scores, including numbers, percentages, and percentiles of categories achieved, trials, errors, perseverative errors, and non-perseverative errors.

Graphomotor Function Tests

(1) Handwriting performance test

For measuring handwriting performance, a short paragraph copy task was performed on an A4-sized sheet in an arrangement of 10 columns with a width of 18 mm. The task is constrained in time for 4 min. The children were told to write as fast and correctly as possible. The number of correct copies was counted for a measure of handwriting performance (Hung, Chang, Chen, Chen, & Lee, 2003).

(2) Computerized handwriting performance evaluation

(a) Measuring Instruments

The handwriting tasks were performed on an A4 size paper affixed to the surface of a 2-D digitizing tablet (487 × 318 × 12 mm, Wacom Intuos 5, Japan) using a wireless electronic-ink pen with a force-sensitive tip (1024 levels). The digital tablet samples the X (horizontal) and Y (vertical) positions of the pen tip as well as the axial pen force, with a maximum frequency of 200 Hz, a spatial accuracy of .01 cm, and a temporal accuracy of 1 ms. The pen used in this study is of a size and weight similar to that of pens typically used by children of this age (length = 150 mm, circumference = 35 mm, weight = 11g).

(b) Handwriting Tasks

(i) Handwriting movement test

This copy test was performed in front of a desktop computer display. The children were instructed to copy the testing tasks presented on the screen. There were 30 Chinese characters in total, presented character by character with an average interval of 15 s. For testing the response time, children were told to move their pen to initiate the first stroke as soon as possible. They were told that they should write as fast and correctly as possible.

(ii) Automation test

For testing automation in handwriting, the children were instructed to write unfamiliar characters with 6 strokes () in the cells. The contents of the page were arranged in five rows and eight columns, giving a grid of 40 cells measuring 18 mm by 18 mm. Before the test, the children were taught to write the characters in a particular sequence. The children used their fingers to indicate that they knew the direction of each stroke. They were required to write the characters 40 times (Chang & Yu, 2010).

The examiner gave instructions and monitored the practice process. After confirming that the children knew how to proceed, the measurement started. The whole process was recorded and the data were saved into a computer hard disk for further offline analysis.

(c) Measuring parameters of graphomotor skills

1. Response time

   The latency between the copy task presented to the start of the first stroke was recorded to test their response time.

2. Mean Stroke Velocity

   In the copy task, the stroke velocity was determined by dividing the stroke length by the elapsed time. The mean value was derived from the average of all the strokes in all of the written tasks.

3. Time to automation in learning an unfamiliar character

   For measuring the level of automation, the number of vertical or horizontal velocity peaks for every vertical or horizontal stroke, respectively, was determined as an approximation of the number of changes in the direction of velocity. This represented the level of automation. An intensive decrease in the number of directional changes of velocity indicated a switch from closed-feedback control to open-loop control (Mergl, Tigges, Schröter, Möller, & Hegerl, 1999).

   To characterize the automation process, the change in the number of directional changes of velocity was described using an exponential function: $Y = A \times e^{-n/t_0} + B$; where Y is the number of directional changes of velocity, n is the number of practice attempts, t0 is the time constant (the time required to reach automation when learning to write a new character), A is a scaling parameter, and B is the asymptotic number of directional changes of velocity at the end of the process. The coefficients A, t0, and B were estimated using the least-squares error method. Automation was defined in this study as 63.21% $(1 - e^{-1})$ reduction in the number of directional changes in velocity (S. H. Chang & Yu, 2010).

Statistical analysis

SPSS for Windows/PC (SPSS Inc., Ver 16.0, Chicago, Illinois) will be used for the statistical analyses. To test the improvement achieved through intervention and to compare the effect on the three groups, we will use a 2×2 repeated-measures analysis of variance (ANOVA) to examine the differences in the measures of the handwriting performance, WCST, and Stroop test. The factors are group (onsite, Wii, control) and time (pre-intervention, post-intervention). A significant interaction effect (Group × Time) indicates a difference in the time effect across the three groups, that is, evidence of an intervention effect.

References

Archer, T., & Kostrzewa, R. M. (2012). Physical exercise alleviates ADHD symptoms: regional deficits and development trajectory. *Neurotoxicity Research, 21*(2), 195-209.

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*: American Psychiatric Pub.

Benzing, V., & Schmidt, M. (2019). The effect of exergaming on executive functions in children with ADHD: A randomized clinical trial. *Scandinavian journal of medicine & science in sports*, 29(8), 1243-1253.

Coulacoglou, C., & Saklofske, D. H. (2017). Psychometrics and psychological assessment: Principles and applications. Academic Press.

Chang, S.-H., & Yu, N.-Y. (2005). Evaluation and classification of types of Chinese handwriting deficits in elementary schoolchildren. *Perceptual and motor skills, 101*(2), 631-647.

Chang, S. H., & Yu, N. Y. (2010). Characterization of motor control in handwriting difficulties in children with or without developmental coordination disorder. *Developmental Medicine & Child Neurology, 52*(3), 244-250.

Danielson, M. L., Bitsko, R. H., Ghandour, R. M., Holbrook, J. R., Kogan, M. D., & Blumberg, S. J. (2018). Prevalence of parent-reported ADHD diagnosis and associated treatment among US children and adolescents, 2016. *Journal of Clinical Child & Adolescent Psychology, 47*(2), 199-212.

Elosúa, M. R., Del Olmo, S., & Contreras, M. J. (2017). Differences in executive functioning in children with Attention Deficit and Hyperactivity Disorder (ADHD). *Frontiers in psychology, 8*, 976.

Frings, M., Gaertner, K., Buderath, P., Christiansen, H., Gerwig, M., Hein-Kropp, C., ... & Timmann, D. (2010). Megalographia in children with cerebellar lesions and in children with attention-deficit/hyperactivity disorder. *The Cerebellum*, 9(3), 429-

432.
Fulk, L., Stock, H., Lynn, A., Marshall, J., Wilson, M., & Hand, G. (2004). Chronic physical exercise reduces anxiety-like behavior in rats. *International journal of sports medicine, 25*(01), 78-82.
Gapin, J., & Etnier, J. L. (2010). The relationship between physical activity and executive function performance in children with attention-deficit hyperactivity disorder. *Journal of Sport and Exercise Psychology, 32*(6), 753-763.
Gomez-Pinilla, F., Zhuang, Y., Feng, J., Ying, Z., & Fan, G. (2011). Exercise impacts brain-derived neurotrophic factor plasticity by engaging mechanisms of epigenetic regulation. *European Journal of Neuroscience,* 33(3), 383-390.
Greve, K. W., Stickle, T. R., Love, J. M., Bianchini, K. J., & Stanford, M. S. (2005). Latent structure of the Wisconsin Card Sorting Test: a confirmatory factor analytic study. *Archives of Clinical Neuropsychology, 20*(3), 355-364.
Hill, L. J., Williams, J. H., Aucott, L., Thomson, J., & MON-WILLIAMS, M. A. R. K. (2011). How does exercise benefit performance on cognitive tests in primary-school pupils? *Developmental Medicine & Child Neurology,* 53(7), 630-635.
Hilton, C. L., Cumpata, K., Klohr, C., Gaetke, S., Artner, A., Johnson, H., & Dobbs, S. (2014). Effects of exergaming on executive function and motor skills in children with autism spectrum disorder: A pilot study. *American Journal of Occupational Therapy*, 68(1), 57-65.
Homack, S., & Riccio, C. A. (2004). A meta-analysis of the sensitivity and specificity of the Stroop Color and Word Test with children. *Archives of Clinical Neuropsychology, 19*(6), 725-743.
Hung, L. Y., Chang, Y. W., Chen, S. F., Chen, C. S., & Lee, Y. D. (2003). *Battery of Chinese Basic Literacy (BCBL)*: Psychological Company.
Lange, K. W., Tucha, L., Walitza, S., Gerlach, M., Linder, M., & Tucha, O. (2007). Interaction of attention and graphomotor functions in children with attention deficit hyperactivity disorder. *Journal of neural transmission,* (Suppl 72), 249-259.
Langmaid, R. A., Papadopoulos, N., Johnson, B. P., Phillips, J. G., & Rinehart, N. J. (2014). Handwriting in children with ADHD. *Journal of attention disorders,* 18(6), 504-510.
Laniel, P., Faci, N., Plamondon, R., Beauchamp, M. H., & Gauthier, B. (2020). Kinematic analysis of fast pen strokes in children with ADHD. *Applied Neuropsychology: Child, 9*(2), 125-140.
Mergl, R., Tigges, P., Schröter, A., Möller, H.-J., & Hegerl, U. (1999). Digitized analysis of handwriting and drawing movements in healthy subjects: methods, results and perspectives. *Journal of neuroscience methods, 90*(2), 157-169.
Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive psychology, 41*(1), 49-100.
Pan, C.-Y., Tsai, C.-L., Chu, C.-H., Sung, M.-C., Huang, C.-Y., & Ma, W.-Y. (2019). Effects of physical exercise intervention on motor skills and executive functions in children with ADHD: A pilot study. *Journal of attention disorders,* 23(4), 384-397.
Racine, M. B., Majnemer, A., Shevell, M., & Snider, L. (2008). Handwriting performance in children with attention deficit hyperactivity disorder (ADHD). *Journal of Child Neurology, 23*(4), 399-406.
Raggi, V. L., & Chronis, A. M. (2006). Interventions to address the academic impairment

of children and adolescents with ADHD. *Clinical Child and Family Psychology Review, 9*(2), 85-111.

Rosenblum, S. (2018). Inter-relationships between objective handwriting features and executive control among children with developmental dysgraphia. *PloS one, 13*(4), e0196098.

Schwartz, K., & Verhaeghen, P. (2008). ADHD and Stroop interference from age 9 to age 41 years: A meta-analysis of developmental effects, *Psychological Medicine*, 38, 1607-1616.

Shallice, T., Marzocchi, G. M., Coser, S., Del Savio, M., Meuter, R. F., & Rumiati, R. I. (2002). Executive function profile of children with attention deficit hyperactivity disorder. *Developmental neuropsychology, 21*(1), 43-71.

Shen, I. H., Lee, T. Y., & Chen, C. L. (2012). Handwriting performance and underlying factors in children with Attention Deficit Hyperactivity Disorder. *Research in developmental disabilities*, 33(4), 1301-1309.

Sibley, B. A., Etnier, J. L., & Le Masurier, G. C. (2006). Effects of an acute bout of exercise on cognitive aspects of Stroop performance. *Journal of Sport and Exercise Psychology, 28*(3), 285-299.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of experimental psychology, 18*(6), 643.

Swain, R. A., Harris, A. B., Wiener, E. C., Dutka, M. V., Morris, H. D., Theien, B. E., . . . Greenough, W. T. (2003). Prolonged exercise induces angiogenesis and increases cerebral blood volume in primary motor cortex of the rat. *Neuroscience, 117*(4), 1037-1046.

Tan, B. W., Pooley, J. A., & Speelman, C. P. (2016). A meta-analytic review of the efficacy of physical exercise interventions on cognition in individuals with autism spectrum disorder and ADHD. *Journal of autism and developmental disorders,* 46(9), 3126-3143.

Tomporowski, P. D., Davis, C. L., Miller, P. H., & Naglieri, J. A. (2008). Exercise and children’s intelligence, cognition, and academic achievement. *Educational psychology review*, 20(2), 111.

Tomporowski, P. D., Lambourne, K., & Okumura, M. S. (2011). Physical activity interventions and children's mental function: an introduction and overview. *Preventive medicine, 52,* S3-S9.

Tsai, C.-L. (2009). The effectiveness of exercise intervention on inhibitory control in children with developmental coordination disorder: Using a visuospatial attention paradigm as a model. *Research in developmental disabilities, 30*(6), 1268-1280.

Tucha, O., & Lange, K. W. (2001). Effects of methylphenidate on kinematic aspects of handwriting in hyperactive boys. *Journal of Abnormal Child Psychology, 29*(4), 351-356.

Tucha, O., Prell, S., Mecklinger, L., Bormann-Kischkel, C., Kübber, S., Linder, M., . . . Lange, K. W. (2006). Effects of methylphenidate on multiple components of attention in children with attention deficit hyperactivity disorder. *Psychopharmacology, 185*(3), 315-326.

Van Praag, H. (2008). Neurogenesis and exercise: past and future directions. *Neuromolecular medicine, 10*(2), 128-140.

Vickers, J. N., Rodrigues, S. T., & Brown, L. N. (2002). Gaze pursuit and arm control of adolescent males diagnosed with attention deficit hyperactivity disorder (ADHD) and normal controls: Evidence of a dissociation in processing visual information of short and long duration. *Journal of sports sciences, 20*(3), 201-216.

Wing, A. M. (2000). Motor control: Mechanisms of motor equivalence in handwriting.

Current Biology, *10*(6), R245-R248.