Title
Attention Deficit Hyperactivity Disorder: Co-Morbidity and Treatment

Author
Jones, Maria Rebecca

Publication Date
2019

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA,
IRVINE

Attention Deficit Hyperactivity Disorder:
Co-Morbidity and Treatment

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Education

by

Maria Rebecca Jones

Dissertation Committee:
Associate Professor Susanne M. Jaeggi, Chair
Chancellor's Professor Carol M. Connor
Professor Priti Shah

2019

DEDICATION

To

Jason and Mia

For their endless love

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

I would like to express the deepest appreciation to my committee chair, Dr. Susanne M. Jaeggi. Susanne, I'll forever be grateful that you took me into your lab. It has been an enriching experience to learn from you and to be a part of the amazing group you have cultivated. Through your mentorship I learned to be a better researcher, a better writer, and a better statistician. I am confident that, because of you, I am a better thinker. I appreciate that you have supported me throughout this program, and even through my "extracurriculars," including a full Ironman and the birth of my baby girl. I'll never forget these wonderful five years with our weekly meetings, lab camping trips, and potluck dinners at your house. Thank you.

I would also like to thank my committee members Dr. Carol Connor and Dr. Priti Shah. Carol, I'm so thankful that you came to UC Irvine, that I was able to take your wonderful classes, that you welcomed me into your lab, and that I was able to teach a course on Exceptional Learners with you. I learned so much from you and benefitted so much from your kindness and support. Working with you helped me develop my confidence in so many ways. Priti, thank you for including me in your research. It was a privilege to work with you on the ADHD studies. You gave me so much freedom to develop my own ideas, and I learned so much. Thank you for trusting and believing in me. You have always been kind and supportive and so much fun to work with.

To my co-authors, thank you for helping me, encouraging me, and giving me so many great opportunities. Martin, when Susanne became my advisor, so did you. I'm so lucky to have had your mentorship throughout the years. Ben, you're my hero. I look up to you. Please take a nap. Osman, thank you for always sharing your insights and for helping me become comfortable with complicated statistics. Sabrina, thank you for including me on your meta-analysis and for being such a good friend.

To my fellow lab mates, thank you for being my academic family. Jacky, thank you for taking me out to lunch and encouraging me to join the WMP lab when I first came to graduate school. That was a good call. Grace, thank you for coming with me to the WMP lab. You taught me how to make error bars on my first year poster and never stopped being gracious with your time. Emily, it takes a special kind of friendship to get through a marathon together. We've definitely seen each other through hard times. Shafee, thank you for your friendship, good Indian food, and for always being up for an adventure. Chus, thank you coming into my life (all the way from Spain), for being an awesome roommate, for the long drives to UCLA, and the long days in San Juan. Chelsea, you will always be my stats guru. You taught me not to be afraid of math, and you've made doing research fun. I'm so glad we worked together in the beginning of my graduate program. We really kicked things off to a fun start with the Bookworm project.

I was so lucky to have the unique pleasure of working with amazing project managers and research assistants. Minnie, I love your joyful, creative spirit. We enjoyed a really unique collaborative relationship. That was a very special era of graduate school for me. Nina, I'm so happy that you joined the lab. You were only here for a short time, but you made quite an impact with your big heart and your super organized brain, and now you're stuck with me for life. Francesca, you are an amazing person. You are kind, smart, insightful, always supportive, a brilliant writer, and an amazing editor. There are not enough words to describe how incredible you are. I honestly don't know how I could have finished this dissertation without you. I also want to thank Mike, Sara, John, Marcela, Bryce, Lara and Shireen for taking leadership roles on my projects. To each research assistant that has ever been a part of the team, thank you from the bottom of my heart. It was a pleasure to work with such bright and enthusiastic young people. Our weekly meetings were the highlight of my graduate school experience. I am forever in your debt for all that you have done.

I would also like to thank my graduate student friends. To Cohort 8: We were in this together, for sure. What a wonderful group. Doron, thank you for the quarterly potlucks, for the many walks, and for being my editing partner. Lauren, we've been close since the beginning. I will always cherish our friendship. Veronica, thank you for the long talks, the words of wisdom, and the constant support. I'm so glad that sharing an office for a few months turned into a wonderful friendship. Shantell and Jenell, thank you for the long bike rides, the long evening swims, donut rides, and racing together in Mexico. You are my biking buddies turned life-long friends. You made a big impact on my PhD experience, and I'm so grateful.

I would like to acknowledge that research in this dissertation was supported by grant No. R324A090164 from the US Department of Education's Institute for Educational Sciences to Priti Shah, grant No. P50HD052120 from the National Institute of Child Health and Development to Richard Wagner, and grant No. 1321846 from the National Science Foundation Division of Graduate Education to myself. I would also like to acknowledge Sage Publishing for permitting me to re-print my article as chapter 3 of this dissertation.

Finally, I would like to thank my family for their unconditional love and support. Jason, your love and encouragement has pushed me to grow and reach my goals. I am so lucky to have you as my husband and best friend. Mia, you are the cutest and sweetest little girl in the world. My little dissertation baby, I'm so happy to be able to cross this finish line with you. And I haven't forgotten Jimmie, the official lab lap dog, who has been by my side for this whole thing, sleeping next to me even now, as I write.

CURRICULUM VITAE
Maria "Masha" R. Jones

EDUCATION

University of California, Irvine
Ph.D in Education
Dissertation: Attention Deficit Hyperactivity Disorder: Co-Morbidity and Treatment
Committee Members: Susanne M. Jaeggi, Carol M. Connor, and Priti Shah
June, 2019
M.A. in Education
June, 2017

University of California, San Diego
B.A. in Linguistics
Specialization in Cognition and Language
June, 2012

PUBLICATIONS

Jones, M. R., Katz, B., Buschkuehl, M., Jaeggi, S. M., & Shah, P. (2018). Exploring n-back cognitive training for children with ADHD. *Journal of Attention Disorders*. https://doi.org/10.1177/1087054718779230

Connor, C. M., Day, S. L., Zargar, E., Wood, T., Taylor, K., Jones, M. R., & Hwang, J. K. (2018). Building word knowledge, learning strategies, and metacognition with the Word-Knowledge E-book. *Computers & Education.* https://doi.org/10.1016/j.compedu.2018.09.016

Katz, B., Jones, M. R., Shah, P., Buschkuehl, M., & Jaeggi, S. M. (2016). Individual differences and motivational effects. In T. Strobach & J. Karbach (Eds.), *Cognitive Training: An Overview of Features and Applications* (pp. 157–166). Springer International Publishing. *Open Psychology.*

Parlett-Pelleriti, C., Lin, G. C., Jones, M. R., Linstead, E. J., & Jaeggi, S. M. (in press). Exploring age-related metamemory differences using calibration and hierarchical clustering.

Lin, G. C., Smith, R. N., Parlett-Pelleriti, C., Jones, M. R., & Jaeggi, S. M. (in press). I bet I'll remember "biochemistry" – Meta-memory as a function of lexical features and language background. Conference Proceedings for the 11th International Conference on the Mental Lexicon 2018.

In Preparation

Jones, M. R., Umanji, O., Trane, F., Zargar, E., Day, S. L., & Connor, C. M. (in preparation). The relations among ADHD symptoms, reading ability, and executive functioning.

Jones, M. R., Lin, G. C. & Jaeggi, S. M. (in preparation). Writing your own quiz questions improves course outcomes.

Solanki, S., Jones, M. R., & Lee, H. (in preparation). Charting college success: A meta-analytic study of motivation interventions.

Katz, B., Jones, M. R., Glazier, J., Buschkuehl, M., Jonides, J., Jaeggi, S. M., & Shah, P. (in preparation). The role of inhibitory processes in n-back working memory training.

Jones, M. R., Trane, F. E., Katz, B., Wu, M., Ozbardakci, N., Buschkuehl, M., Shah, P., & Jaeggi, S. M. (in preparation). Motivation Intervention for children and adolescents with ADHD.

Jones, M. R. & Jaeggi, S. M. (in preparation). Creativity in adolescents with ADHD.

Wood, T., Jones, M. R., Umanji, O., Connor, C. M. (in preparation). Teacher experience and gender influences on math achievement in first grade.

FELLOWSHIPS AND AWARDS

2015–2019	National Science Foundation, Graduate Research Fellowship Program
2018	$10,000 Seed Grant from the University of California Consortium on the Developmental Science of Adolescence
2017	Associated Graduate Students Symposium Audience Choice Award for Best Research Talk
2017	Finalist for $30,000 seed grant from the UCI Institute for Clinical and Translational Science
2017	UCI "Grad Slam" Research Talk Semi-Finalist
2016	National Institute of Health-funded Fellow, University of Michigan Training Course in fMRI
2016	Graduate student travel award, International Meeting of the Psychonomic Society in Granada, Spain

INVITED TALKS

2018	Jones, M. R. (2018, June). *Cognitive and metacognitive interventions for ADHD.* Paper presented in the Stigler lab at UCLA, Los Angeles, CA.

CONFERENCE PRESENTATIONS

Kukreja, S., Trane, F. E., Jones, M. R., & Jaeggi, S. M. (2019, May). *Gender Differences in Inhibitory Control Among Children with ADHD.* Poster presented at the 31st American Psychological Association Annual Convention, Washington DC.

Zheng, Y., Trane, F. E., Jones, M. R., & Jaeggi, S. M. (2019, May). *The Impact of Parent's ADHD Symptoms on Persistence and Mindset in Children with ADHD.* Poster presented at the 31st American Psychological Association Annual Convention, Washington DC.

Khan, S., Jones, M. R., Trane, F. E., Jaeggi, S. M. (2019, May). *Exploring Differences in Convergent and Divergent Thinking in Children with ADHD.* Poster presented at the 31st American Psychological Association Annual Convention, Washington DC.

Barakat, L., Jones, M. R., Trane, F. E., & Jaeggi, S. M. (2019, April). *Inhibitory control and creativity in children with ADHD.* Poster presented at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

Rojas-Montes De Oca, Y., Jones, M. R., Trane, F. E., & Jaeggi, S. M. (2019, April). *Perceived effectiveness of motivation and study skill interventions for children with ADHD.* Poster presented at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

Trane, F. E., Ozbardakci, N., Jones, M. R., Umanji, O., & Jaeggi, S. M. (2019, April). *Character strengths of youth with learning and attention disorders.* Poster presented at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

Carson, B., Jones, M. R., Trane, F. E., Jaeggi, S. M. (2019, April). *Examining divergent thinking in youth with and without ADHD.* Poster presented at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

Khan, S., Jones, M. R., Trane, F. E., Jaeggi, S. M. (2019, April). *Analyzing creativity in children with ADHD.* Poster presented at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

Burt, S., Jones, M. R., Trane, F., E., & Jaeggi, S. M. (2019, April). *Motivational intervention for children with ADHD.* Poster presented at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

Zheng, Y., Trane, F. E., Jones, M. R., & Jaeggi, S. M. (2019, April). *ADHD Subtype as predictor for effectiveness of motivational intervention.* Poster presented at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

Zeng, K., Kukreja, S., Trane, F. E., Jones, M. R., & Jaeggi, S. M. (2019, April). *The Effect of parent ADHD symptoms on child persistence, motivation and mindset.* Poster presented at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

Smith, R., Lin, G. Parlett-Pelleriti, C., Jones, M. R., & Jaeggi, S. M. (2019, April). *Investigating the underconfidence-with-practice effect in a novel metamemory task.* Poster presented at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

Jones, M. R., Umanji, O., Trane, F., Zargar, E., Day, S. L., & Connor, C. M. (2019, January). *How ADHD symptoms relate to word reading and reading comprehension.* Poster presented at the American Professional Society of ADHD and Related Disorders, Washington, DC.

Trane, F. E., Jones, M. R., Umanji, O., & Jaeggi, S. M. (2019, January). *Self-perceived character strengths of youth with ADHD.* Poster presented at the American Professional Society of ADHD and Related Disorders, Washington, DC.

Lin, G., Smith, R., Parlett-Pelleriti, C., Jones, M. R., & Jaeggi, S. M. (2018, September). *I bet I'll remember "biochemistry" – Metamemory as a function of lexical features and language background.* Poster presented at the 11th international conference on the mental lexicon, Edmonton, Canada.

Jones, M.R., Wu, M., Trane, F., Ozbardakci, N., Burt, S., Tourchian, M., Katz, B., Buschkuehl, M., Jaeggi S. M., & Shah, P. (2018, May). *Motivation intervention for children with ADHD.* Poster presented at the 30th Annual Association for Psychological Science Convention, San Francisco, CA.

Ozbardakci, N., Trane, F., Jones, M.R., Wu, M., Katz, B., Buschkuehl, M., Jaeggi S. M., & Shah, P. (2018, May). *How Coping Strategies and Stimulant Medication Relate to Mindsets and Persistence in Children with ADHD.* Poster presented at the 30th Annual Association for Psychological Science Convention, San Francisco, CA.

Trane, F., Khan, S., Dee, J. I., Jones, M.R., Wu, M., Ozbardakci, N., Buschkuehl, M., Jaeggi S. M., & Shah, P. (2018, May). *Relationships among parental mindsets and persistence and motivation in children with ADHD.* Poster presented at the 30th Annual Association for Psychological Science Convention, San Francisco, CA.

Jones, M. R., & Connor, C. M. (2018, April). *Attention Deficit Hyperactivity Disorders and Reading Skills.* Round table presentation at American Educational Research Association Conference, New York, NY.

Khan, S., Dee, J. I., Trane, F., Jones, M. R., Ozbardacki, N., Buschkuehl, M., Jaeggi, S. M., & Shah, P. (2018, April) *The influence of parental mindsets on persistence and motivation in children with ADHD.* Poster presented at the Western Psychological Association Convention, Portland, OR.

Katz, B., Jones, M. R., Buschkuehl, M., Jaeggi, S. M., & Shah, P. (2018, January). *Improving attention in ADHD children with computerized lure-adaptive working memory training.* Poster presented at the Annual Principle Investigator Meeting of the Institute of Education Sciences, Arlington, VA.

Solanki, S., Jones, M. R., & Lee, H. (2017, November). *What works for college student success? A Meta-Analytic Study of Motivation Interventions.* Poster presented at Association for Public Policy Analysis and Management Annual Research Conference, Chicago, IL.

Parlett, C., Mohammed, S., Katz, B., Shah, P., Zabel, C., Au, J., Jones, M. R., Buschkuehl, M., Reuter-Lorenz, P. A., Jonides, J., & Jaeggi, S. M. (2017, January). *The effect of spacing in older adults: working memory training.* Poster presented at Aging and Cognition Conference, Dallas, TX.

Jones, M. R., Katz, B., Jaeggi S. M., Buschkuehl, M., & Shah, P. (2016, November). *Cognitive training improves inhibitory control and ADHD symptoms.* Poster presented at the Annual Meeting of the Psychonomic Society, Boston, MA.

Katz, B., Jones, M.R., Glazer, J., Wu, M., Jonides, J., Buschkuehl, M., Jaeggi S.M., & Shah, P. (2016, November). *The role of lures in n-back training.* Poster presented at the Annual Meeting of the Psychonomic Society, Boston, MA.

Jones, M. R., & Jaeggi, S. M. (2016, May). *Enhancing the testing effect.* Poster presented at the International Meeting of the Psychonomic Society, Granada, Spain.

Jones, M. R., Maraver, M. J., Bajo, M. T., Gomez-Ariza, C., Parlett, M., Au, J., Buschkuehl, M., & Jaeggi, S. M. (2016, May). *Working memory training for low- and high-ability readers.* Poster presented at the International Meeting of the Psychonomic Society, Granada, Spain.

Maraver, M. J., Jones, M. R., Bajo, M. T., Gomez-Ariza, C., Parlett, Au, J., Buschkuehl, M., & Jaeggi, S. M. (2016, May). *Individual differences in motivation, attention and supervision during working memory training in elementary school children.* Poster presented at the International Meeting of the Psychonomic Society, Granada, Spain.

Parlett, C., Jones, M. R., Maraver, M. J., Bajo, M. T., Gomez-Ariza, C., Au, J., Buschkuehl, M., & Jaeggi, S. M. (2016, May). *Working memory training: predicting transfer*. Poster presented at UCI Data Science Symposium: Fostering Literacy and Learning with Text and Data Mining, Irvine, California.

UNIVERSITY TEACHING AND MENTORING

University of California, Irvine

2018	Exceptional Learners: TA with co-instructor responsibilities including lecturing, course design, assessment and rubric creation. Approximately 60 students.
2015–2018	Undergraduate Directed Research Seminar: Primary instructor for quarterly small group courses (5–10 students), focusing on reading and discussing primary research.
2014–2015	Introduction to Early Childhood Education: Teaching assistant for two quarters. Approximately 60 students.

Guest lectures

2018	Language and Reading Development: California State University, Long Beach course entitled Child Development. Approximately 35 students.
2015	Reading Development and Disorders: UC Irvine undergraduate course entitled Cognition and Learning in Educational Settings. Approximately 60 students.
2015	Professionalism in Early Childhood Education: UC Irvine undergraduate course entitled Introduction to Early Childhood Education. Approximately 60 students.
2015	Differentiating Instruction in the EFL Classroom: UC Irvine undergraduate course entitled Teaching English Internationally. Approximately 60 students.

Supervised Undergraduate Student Projects
$13,525 in undergraduate research funding

Kukreja, S. (2019). *Gender differences in inhibitory control among children with ADHD.* Undergraduate Research Opportunities Fellowship, UC Irvine.

Khan, S., & Carson, B., (2019). *The Effects of Medication on Inhibitory Control in Children with ADHD as Observed in Lab and in Context.* Undergraduate Research Opportunities Fellowship, UC Irvine.

Barakat, L. (2019). *Among an Array of Skills, which Emerges as the Greatest Resource for Students with ADHD?* Undergraduate Research Opportunities Fellowship, UC Irvine.

Zheng, Y. (2019). *Do Children with ADHD and Dyslexia Differ in Divergent Thinking Abilities?* Undergraduate Research Opportunities Fellowship, UC Irvine.

Rojas-Montes De Oca, Y. (2019). *ADHD: Perceived Effectiveness of Motivation and Study Skill Interventions.* Undergraduate Research Opportunities Fellowship, UC Irvine.

Dee, J. I. (2018). *Intelligence mindsets and persistence in girls with ADHD*. Campus-Wide Honors Program Thesis, UC Irvine.

Khan, S. (2018). *Creative storytelling in children with ADHD.* Summer Undergraduate Research Opportunities Program Fellowship, UC Irvine.

Carson, B. (2018). *Creativity and inhibitory control in children with ADHD.* Summer Undergraduate Research Opportunities Program Fellowship, UC Irvine.

Barakat, L. (2018). *Do children with ADHD show better performance on tests of divergent thinking in comparison to their peers?* Summer Undergraduate Research Opportunities Program Fellowship, UC Irvine.

Zeng, K. (2018). *How do parent ADHD symptoms influence child persistence and motivation?* Honorary Undergraduate Research Opportunity Program Fellowship, UC Irvine.

Tourchian, M. (2018). *Combined cognitive and motivational intervention for children with ADHD*. Undergraduate Research Opportunity Program Fellowship, UC Irvine.

Khan, S. & Dee, J. I. (2017). *Parental influences on mindsets, motivation, and persistence in ADHD.* Undergraduate Research Opportunities Program Fellowship, UC Irvine.

Tourchian, M. (2017). *Motivational intervention for children with ADHD.* Summer Undergraduate Research Opportunities Program Fellowship, UC Irvine.

Pranajasa, T. (2017). *The influences of affect and rumination on creative thinking*. Campus-Wide Honors Program Thesis, UC Irvine.

Feri, J. & Pranajasa, T. (2016). *Individual differences in creative reasoning*. Undergraduate Research Opportunities Program Fellowship, UC Irvine.

OTHER TEACHING

Language and Scholastics

Full time English as a Second Langauge Instructor for adult/college-aged immigrants (August, 2012–September, 2014; Head teacher October, 2013–September, 2014).

Pepperdine University, Irvine, CA

Master teacher, mentor for MA TESOL candidate (May–July 2014).

PROFESSIONAL SERVICE

Ad-hoc Reviewer for:

2018 *Developmental Psychology*
2018 *Review of Educational Research*
2017 *AERA Open*
2017 *Journal of Cognitive Enhancement*
2017 *Cognitive Development*
2016 *Infant and Child Development*
2016 *Developmental Cognitive Neuroscience*

2016–2017 UCI President of the Associated Doctoral Students in Education
2015–2018 UCI Peer Mentor for the Diverse Educational Community and Doctoral Experience
2015–2016 UCI Vice President of Associated Doctoral Students in Education

MEDIA COVERAGE

2018 Guest on the Inclusive Education Podcast: Discussion of unique strengths associated with ADHD and learning disabilities. https://goo.gl/TTv6Pt

CERTIFICATIONS

2016 Excellence in Course Design, UC Irvine Division of Teaching Excellence and Innovation
2016 Excellence in Mentorship, UC Irvine Graduate Resource Center

ABSTRACT OF THE DISSERTATION

Attention Deficit Hyperactivity Disorder:

Co-Morbidity and Treatment

By

Maria Rebecca Jones

Doctor of Philosophy in Education

University of California, Irvine, 2019

Associate Professor Susanne M. Jaeggi, Chair

Attention Deficit Hyperactivity Disorder (ADHD) is a common, yet complex and heterogeneous developmental disorder. Our understanding of co-morbidity in ADHD lacks nuance, despite the fact that it is frequently co-diagnosed with other developmental disorders, including reading disabilities. Furthermore, the available interventions for ADHD, such as stimulant medication and behavioral therapy, are not universally effective, necessitating the development of alternative or supplementary treatment options. This dissertation draws from the Dual Pathway model of ADHD, which suggests that ADHD is the result of underlying executive dysfunction and/or motivational problems associated with delay aversion, in order to investigate co-morbidity in and novel treatments for ADHD.

In Study 1, I use hierarchical linear modeling to develop a clearer understanding of the associations between ADHD symptoms, reading challenges, and executive functioning. I show that ADHD symptoms are more strongly related to reading comprehension than to word reading, and that executive functioning partially explains the associations between ADHD symptoms and

reading ability. In Studies 2 and 3, I test the effectiveness of randomized control trials for children with ADHD: the first is an executive function training intervention and the second is a motivation intervention. In study 2, I demonstrate that executive function training has the potential to improve ADHD symptoms, working memory and inhibitory control, in particular. In Study 3 I show that it is feasible to teach concepts from motivation theory, such as growth mindset, to children with ADHD and their parents. Findings from this dissertation underscore the importance of acknowledging the complex etiological heterogeneity in ADHD, which has implications for treatment. They demonstrate that executive functioning alone cannot explain co-morbidity and that the development and implementation of multiple methods of intervention (e.g., executive function training and motivation interventions) is likely necessary, as children may need more than one type of treatment or a tailored treatment plan to target the complexity of their ADHD symptoms.

CHAPTER 1

Introduction

All children and adolescents should have the opportunity to experience success in learning. Unfortunately, classroom-based learning is an enormous challenge for students with Attention Deficit Hyperactivity Disorder (ADHD), many of whom receive co-morbid diagnoses, have academic performance problems and a higher incidence of grade retention and dropping out of school compared to their peers (DuPaul & Stoner, 2014; Pastor & Reuben, 2002). Extending from these academic struggles arise socio-emotional struggles such as students perceiving themselves to be less capable than others. Such negative self-perceptions in turn affect school achievement beyond the negative effects of the students' learning challenges. Interpersonal relationships can also be affected, and together with the academic and other socio-emotional problems result in higher rates of depression and suicide compared to these students' peers (Huntington & Bender, 1993).

ADHD is a commonly diagnosed developmental disorder characterized by inattention, hyperactivity, and impulsive behavior. Approximately 11% of US children have a history of ADHD diagnosis, and 9% of children have a current diagnosis of ADHD (Visser et al., 2014), though prevalence rates vary across studies (Moffitt et al., 2015; Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014). ADHD symptoms typically arise early in childhood (Visser et al., 2014) and continue through adolescence, and will persist into adulthood for 30–60% of individuals diagnosed (Barkley, 1997; Barkley, Fischer, Smallish, & Fletcher, 2002; Faraone, Biederman, & Mick, 2005; Matte et al., 2015; Moffit et al., 2015).

ADHD is a complex disorder. It is difficult for any single theoretical model to fully explain the clinical manifestations of ADHD. Yet, it is from theory that we are able to test hypotheses and design interventions. Thus, this dissertation draws from the Dual Pathway Model: understanding that executive dysfunction plays a major role in ADHD symptomatology and co-morbid disorders, but that motivational factors are also significant contributors (Sonuga-Barke, 2002). By attending to both the executive functioning (EF) and motivational patterns predicted by this model and found amongst children with ADHD, this dissertation aims:

(1) to better understand co-morbidity by examining the relations among ADHD symptoms, reading skills, and EF and

(2) to develop and test interventions aimed at improving EF and motivation in children with ADHD.

Through this work, I hope to influence future interventions that will improve academic achievement and promote positive self-perceptions among students with ADHD.

The Dual Pathway Model

Theory is a critical contributor to clinically-relevant research, as the assumptions within a theory guide the development and testing of interventions. They provide a framework that allows the researcher to identify potentially modifiable variables. Until recently, neuropsychological research has focused on finding a single core deficit to explain the symptoms of ADHD (Pennington, 2005; Sonuga-Barke, 1998). This has been a major limitation in the progress of ADHD research. More recently, ADHD has been recognized as a construct that includes multiple neuropsychological profiles that may be dissociable but overlapping (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006). Major contemporary theories consider poor self-regulation and motivational factors to be the leading factors contributing to ADHD (see Maniadaki & Kakouros, 2017 for a review). Each theory explores the potential causes of ADHD from different angles. For example, some approach ADHD from neurochemical, neuroanatomical, and neurocomputational perspectives (Frank, 2005; Nigg & Casey, 2005; Tripp & Wickens, 2008; Williams & Dayan, 2005), while others focus on the management of arousal states (Sergeat, Oosterlaan, & van der Meere, 1999) or on patterns of alterations in fundamental reinforcement learning processes (Sagvolden, Johansen, Aase, & Russell, 2005).

While no one theory fully captures the complexity of deficits associated with ADHD, I focus on the Dual Pathway model. The Dual Pathway model of ADHD encompasses the Executive Dysfunction theory and the Delay Aversion theory. Together, this model aims to understand how both executive functioning and motivation play a role in ADHD.

Executive Dysfunction Theory. The Executive Dysfunction theory of ADHD from Russel Barkley (1997) is the most well researched theory of ADHD, and it is well supported (Bitsakou, Psychogiou, & Thompson, 2008; Nigg, 2005; Pennington & Ozonoff, 1996; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Willcut, Doyle, Nigg, Faraone, & Pennington, 2005). Barkley's model argues that the primary impairment in ADHD is poor EF, with inhibitory control identified as a main, underlying source of impairment. EF, otherwise referred to as cognitive control, includes the range of higher-order mental processes that regulate cognition and support goal-directed behavior. According to Miyake and colleagues' (2000) model of EF, there are three key EFs: updating/working memory, shifting, and inhibitory control. Updating/working memory involves the monitoring of information to be stored and manipulated in conscious thought. It is the ability to actively manage the items being attended to by replacing older, irrelevant, information with newer, more relevant information. Shifting is the ability to switch attention between tasks and to adjust mental sets to meet changing demands and expectations. Inhibitory control encompasses the ability to purposefully inhibit dominant attentional and behavioral responses. This includes the ability to focus attention on relevant information in the face of competing, distracting information;

it also refers to the capacity to override an impulsive or inappropriate response in favor of a more adaptive, but less natural response.

According to the Executive Dysfunction theory, atypical EF in ADHD results in a reduced ability to execute goal-directed responses or to persist on a task in the face of disruption (Barkley, 1997). However, evidence suggests that executive dysfunction is only present approximately half of individuals with ADHD (Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005), suggesting that Executive Dysfunction theory, while useful in developing an understanding of ADHD, does not represent the entire picture.

Delay Aversion Theory. Delay Aversion theory, put forth by Sonuga-Barke and colleagues (1992), suggests that ADHD behaviors are functional expressions of an underlying motivational style. The term “delay aversion” relates to the idea that individuals with ADHD perform poorly on EF tasks not necessarily because of a cognitive deficit, but rather because of a strong desire to reduce the trial length. In other words, because participants with ADHD tend to strongly dislike performing EF tasks, they may do their best to get through the EF tasks quickly, resulting in low scores that may be misinterpreted by researchers as a demonstration of low EF. While there are individual differences in the greater population in terms of how intrinsically motivated one is or how tolerant of boredom one is, Sonuga-Barke and colleagues suggest that individuals with ADHD have a particularly negative emotional response to delay. Depending on the situation, this delay aversion manifests itself as impulsivity when the individual with ADHD attempts to do things very quickly in order to reduce trial length. The delay aversion can also manifest as inattention when the individual with ADHD attempts to distract themselves from the boredom of waiting by paying attention to something else (e.g. daydreaming). In addition, delay aversion can look like hyperactivity when an individual with ADHD attempts to distract themselves from the boredom of waiting by fidgeting or moving around. Finally, delay aversion can manifest as choice for smaller, immediate rewards over larger, deferred rewards. This preference contributes to the characteristic difficulties of children with ADHD such as low persistence, low frustration tolerance, and low intrinsic motivation (i.e., lack of desire to do well) on non-preferred activities.

The Dual Pathway Model. Sonuga-Bark's more contemporary theory of ADHD integrates this Delay Aversion theory and the Executive Dysfunction theory. This model (Sonuga-Barke, 2002) explains that there are two pathways leading to the clinical expression of ADHD. The first, drawn from Barkley's work, is a cognitive pathway, which includes diminished EF. Deficits in this pathway lead to problems with planning, emotion regulation, and self-regulation. The second pathway is the motivation/delay aversion pathway. The dual pathway model suggests that symptomatology resulting from deficits in this dimension only manifest themselves in delay-rich environments or when there is a high social expectation of impulse control (e.g., school).

According to this theory, individuals can have impairments in one or both pathways. Those with executive dysfunction but without delay aversion are more likely to present with the inattentive subtype of ADHD (i.e., they lack the symptoms of hyperactivity/impulsivity; Chhabildas, Pennington, & Willcutt, 2001; Wåhlstedt, Thorell, & Bohlin, 2009; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005), whereas those with delay aversion are more likely to present with symptoms of hyperactivity and impulsivity (Castellanos et al., 2006). One study found that 29% of children with ADHD displayed both delay aversion and executive dysfunction, 27% displayed delay aversion only, 15% displayed executive dysfunction only, and 29% displayed neither problem (Sonuga-Barke, Dalen, & Remington, 2003). Thus, the Dual Pathway model fails to account for nearly one third of children, at least in that sample, who have a diagnosis of ADHD. This confirms that this model, while accounting for much greater heterogeneity than the Executive Dysfunction theory alone, still fails to explain the full complexity of the disorder.

Comorbidity in ADHD

In order to develop interventions to support children with ADHD, it is important to acknowledge and understand the high rates of co-morbidity in that population, as doing so may inform the development of interventions that can address not only ADHD symptoms but can simultaneously target underlying factors contributing to highly comorbid conditions. Using the Dual Pathway Model to understand how ADHD may relate to a highly comorbid disorder may help researchers uncover mechanisms common to both that can be targeted in intervention work.

ADHD has the highest co-morbidity rate in psychopathology (Maniadaki & Kakouros, 2017). Depending on the sample, studies have found that 60–100% of individuals with ADHD are diagnosed with at least one other disorder (Biederman, Faraone, Keenan, Steingard, & Tsuang, 2001; Ishii, Takahashi, Kawamura, & Ohta, 2003; Kadesjö, 2000; Spencer, 2006). Meta-analytic evidence estimates that 45% of individuals with ADHD experience co-morbid learning disabilities (Dupaul, Gormley, & Laracy, 2013), the most common of which is reading disorder (RD), present in 18.9–44% of individuals with ADHD (Carroll, Maughan, Goodman, & Meltzer, 2005; Pastor & Reuben, 2002). Given these high rates of co-morbidity in ADHD, it is important to understand how these disorders relate to one another. Developing our understanding of the relations between ADHD and co-morbid disorders may inform interventions as well as diagnostic and teaching practices to optimally support students struggling with these issues.

Because RD is the most frequently co-occurring disorder with ADHD, I examine how reading abilities relate to ADHD symptoms in an effort to better understand co-morbidity in ADHD. Drawing from the Executive Dysfunction branch of the Dual Pathway model, I hypothesize that a potential source of the co-occurrence of the disorders is a deficit in EF, suggesting that interventions targeting EF may be beneficial for simultaneously targeting both ADHD and RD (in particular, RD subtypes that are most impacted by EF deficits).

Given that EF is essential for performing complex tasks, it is not surprising that these cognitive skills are necessary for proficient reading processes. While some studies suggest that the relation between reading and EF does not vary as a function of types of reading (Peng et al., 2018), the contribution of EF to reading comprehension has been widely recognized, especially when students are reading more complex and longer texts, where reading strategies need to be utilized (Eason, Goldberg, Young, Geist, & Cutting, 2012). Indeed, the specific EF dimensions of working memory, shifting, and inhibitory control have been demonstrated to play important roles in reading comprehension (Cartwright, 2015; Kendeou, Helder, Van den Broek, & Karlsson, 2014; Yeniad, Malda, Mesman, Van Ijzendoorn, & Pieper, 2013). Working memory is essential for processing incoming information while keeping the prior information active and integrating these different pieces of information together (Daneman & Carpenter, 1980). Moreover, the ability to maintain information in working memory is important for inference making and monitoring one's comprehension. Inhibitory control allows the reader to suppress irrelevant information, while determining which information is relevant and to be maintained in working memory (Cain, 2006; Henderson, Snowling, & Clarke, 2013). Therefore, inhibitory control is also an important component necessary for good comprehension skills (Gernsbacher & Faust, 1991). Finally, the ability to shift between concepts is critical in order to select and maintain appropriate strategies and disengagement from irrelevant ones (Yeniad et al., 2013). Consequently, weaknesses in EF can reduce the reader's ability to effectively comprehend complex texts.

Drawing from this work and from the Dual Pathway model, chapter 2 examines the associations among ADHD symptoms, word reading, and reading comprehension and how those relate to EF in order to understand what type of reading problems children with ADHD are most likely to have and whether such associations can be explained by EF. If they can, then interventions targeting EF may be beneficial in supporting children with ADHD and co-morbid RD.

Interventions for ADHD

There are various approaches for ameliorating the challenges associated with ADHD. The most common method is stimulant medication. There are also non-pharmacological strategies, the most common of which are behavioral interventions. However, each of these has drawbacks, calling for the development of additional treatment options. Drawing from the Dual Pathway model, I focus on targeting executive functioning and motivation, while first reviewing the two most common treatment options for individuals with ADHD: medication and behavioral therapy.

Medication. Although medication can be of great help, they are ineffective for up to 30% of individuals with ADHD (Banaschewski, Roessner, Dittmann, Santosh, & Rothenberger, 2004). Furthermore, though ADHD medications are often seemingly effective in laboratory contexts, they tend to have less impact on everyday functional outcomes (Pelham et al., 2017). In addition, they are often associated with side effects such as sleep disturbances, reduced appetite (Banaschewski et al., 2004), and reduced weight gain during the first two years of medication use (Zachor, Roberts, Bart Hodgens, Isaacs, & Merrick, 2006). For these and other reasons, approximately 20% of individuals with ADHD cease stimulant use within the first year of taking them (Toomey, Sox, Rusinak, & Finkelstein, 2012). Interested readers may refer to Rubia et al. (2014) for a complete meta-analytic review.

Behavioral Therapy. The most widely used non-pharmacological intervention for children with ADHD is behavioral management therapy (Evans, Owens, & Bunford, 2013; Wolraich et al., 2011). In these interventions, teachers (behavioral classroom management), or parents (behavioral parent therapy) are taught to reinforce children when they perform a desired behavior and to ignore undesired behaviors. This approach helps children to learn self-regulation skills, with typical outcomes including improved compliance to parent and teacher directions, as well as decreased disruptive behavior in the classroom. While behavioral therapies are generally considered the most effective non-pharmacological approaches for addressing ADHD symptomatology (Evans et al., 2013; Fabiano et al., 2009), many issues prevent these interventions from being available and effective for all children. Behavioral therapies can also incur significant financial and time investments. Furthermore, new meta-analytic work suggests that although behavioral therapies may be successful in individual studies, a variety of factors related to both the design of the intervention and individual difference factors across participants may limit their effectiveness (Sonuga-Barke et al., 2013).

Cognitive Training. One potential approach to treating ADHD is to target EF, one of the two underlying ADHD deficits identified by the Dual Pathway model. Currently, the most widespread and highly researched cognitive intervention for ADHD is Cogmed working memory training (CWMT), an online working memory training program that primarily targets the storage aspects of both verbal and visuospatial working memory. It is marketed to schools and clinicians as a tool for improving cognitive abilities, such as attention and reasoning (Roberts et al., 2016). Some studies of CWMT in children with ADHD have shown improvements in ADHD-related symptoms as a function of training (Beck, Hanson, Puffenberger, Benninger, & Benninger, 2010; Klingberg et al., 2005; Klingberg, Forssberg, & Westerberg, 2002; Mezzacappa & Buckner, 2010), and a recent study by Bigorra, Garolera, Guijarro, and Hervas (2016) demonstrated reductions in inhibitory control. However, others have failed to replicate those findings, leading to conflicting reviews and meta-analyses (Chacko et al., 2013; van der Donk, Hiemstra-Beernink, Tjeenk-Kalff, van der Leij, & Lindauer, 2015; Shipstead, Hicks, & Engle, 2012). Additional challenges regarding CWMT include lengthy sessions (approximately 40 minutes per day over the course of 5 weeks), the necessity of a coach, and the significant cost (Chacko et al., 2014).

Other cognitive training work has attempted to target inhibition directly. Shavlev, Tsal, & Mevorach (2002), found improvements in attention and academic outcomes following an attentional control training program. Conversely, a recent large, randomized controlled trial of inhibitory control training found no evidence for training and transfer effects (Enge et al., 2014). Although some of the evidence is mixed, it may remain possible to train inhibition, especially if it occurs in combination with training working memory, as there seems to be considerable overlap between the domains of working memory and inhibitory control (Hsu, Jaeggi, & Novick, 2017).

Our intervention, reported in chapter 3 and published in Sage Publishing's *Journal of Attention Disorders* (Jones, Katz, Buschkuehl, Jaeggi, & Shah, 2018), targets EF by way of the n-back task, which requires participants to respond to a series of stimuli, judging whether each stimulus is the same as the one presented n-items previously. The n-back task requires both active maintenance and updating of items in working memory as well as deleting items that are further back in a sequence. It also requires inhibiting responses to near target items, or lures. In previous work, Jaeggi and colleagues (2011), found that children who participated in n-back training outperformed their peers in a control condition on a measure of inhibitory control. These results suggest that n-back training may be especially beneficial for children with ADHD, given that at least half of them are thought to have underlying EF issues, inhibitory control deficits in particular.

Motivation Interventions. According to the Dual Pathway model, individuals with ADHD are particularly intolerant of boredom (Sonuga-Barke, 2002). This makes it difficult for them to persist on challenging or non-preferred tasks. Thus, the second intervention, reported in chapter 4 of this dissertation is a motivation intervention with the goal of improving persistence among children with ADHD. This was attempted by teaching children to set long-term goals, to view intelligence as modifiable through continuous effort, and to overcome frustration by using strategies. Interventions with typically developing participants aimed at altering beliefs about the malleability of intelligence, self-efficacy, and emotional control have been well researched, with promising results. In several randomized control trials, students who were taught that intelligence could be developed and that the brain could change with learning were more likely to endorse a growth mindset (Aronson et al., 2002, Blackwell et al., 2007, Yeager et al., 2016), show improvement in motivation and persistence (Blackwell et. al, 2007), demonstrate improved grade trajectories (Blackwell et al., 2007), receive higher standardized test scores (Good et al., 2003), and demonstrate higher grade point average (Arson et al., 2002; Yeager et al., 2016). However, motivation interventions are not universally beneficial. Across multiple studies, “at-risk” students seemed to benefit the most (Schwartz, Cheng, Salehi, & Wieman, 2016). As children with ADHD are particularly at risk for having poor motivational patterns, they may have the potential to benefit greatly from such an intervention.

Goals and Aims

The goal of this dissertation is to advance our understanding of co-morbidity in ADHD and our ability to treat ADHD and related co-morbid disorders through non-pharmacological interventions. Given the considerable overlap between ADHD and RD, it is important to understand the relations between to two disorders from a theoretical perspective. Thus, drawing from the Executive Dysfunction branch of the Dual Pathway model, the aim of chapter 2 is to understand how EF and ADHD symptoms relate to various reading skills, with the goal of understanding what type of reading problems are more likely to occur along with ADHD. This work may lead to the development of interventions that successfully target both ADHD and the more commonly occurring RD subtype.

It is also important to develop and test theory-driven interventions that support this population. Continuing to draw from the role of Executive Dysfunction in the Dual Pathway model, the aim of chapter 3 is to test the efficacy of a cognitive training program designed specifically to address inhibitory control deficits among children with ADHD. Drawing from the Delay Aversion branch of the Dual Pathway Model, the aim of chapter 4 is to test the efficacy of a motivation intervention designed to teach children with ADHD to persist in the face of frustration, focusing on long-term rewards despite a likely aversion to delay. Chapter 5 provides a general summary and discussion of the three studies (chapters 2–4), their implications, and the potential direction of future work.

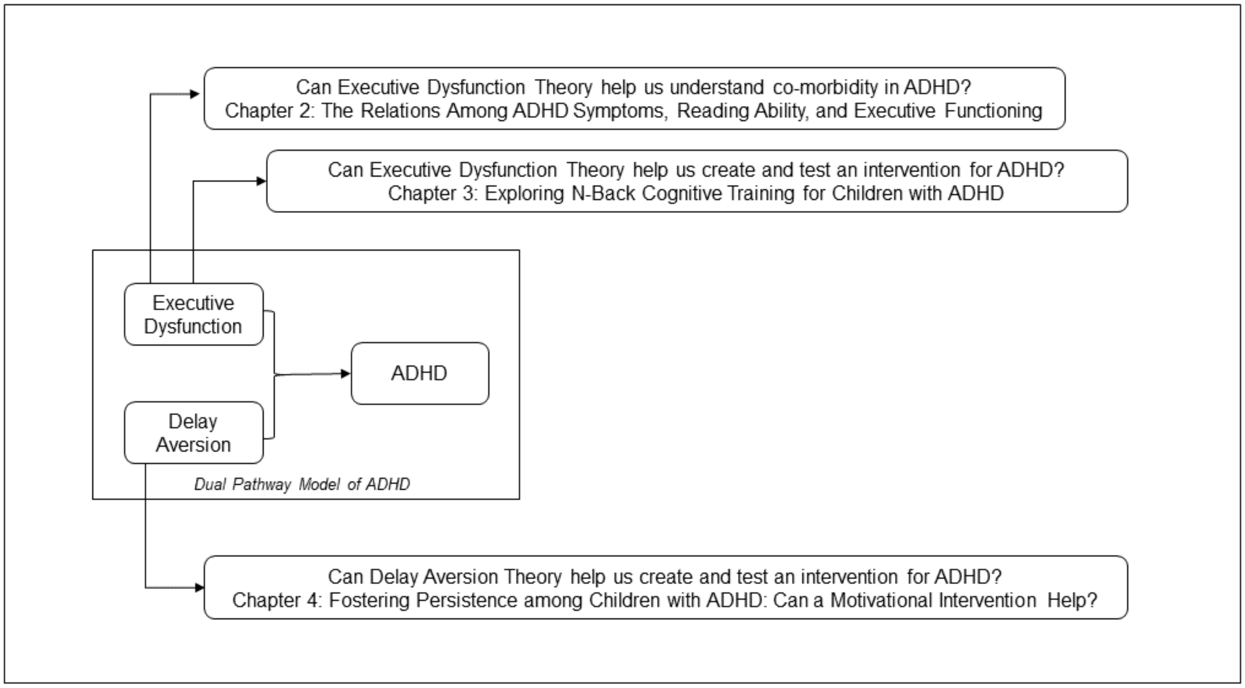


Figure 1.1: The organization of this dissertation and how it relates to Sonuga-Barke's (2002) Dual Pathway Model of ADHD.

Overview of the Chapters

Chapter 2. The Relations among ADHD Symptoms, Reading Ability, and Executive Functioning.

ADHD and RD are frequently co-diagnosed (Pastor & Reuben, 2002). Low executive functioning (EF) is often present in children with ADHD and in children with reading problems (Carretti, Borella, Cornoldi, & De Beni, 2009; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005), with some evidence suggesting a stronger link between low EF and reading comprehension as compared to word reading (Cutting, Materek, Cole, Levine, & Mahone, 2009). In this study, I examine how ADHD symptoms relate to various components of reading. In a community sample of 5th graders (approximately age 10), I test whether ADHD symptoms are more strongly correlated with reading comprehension than with word reading, and whether this association is mediated by EF. I find that ADHD symptoms are more closely related to reading comprehension than word reading, and that both associations are partially mediated by EF. These findings suggest that interventions targeting executive dysfunction in ADHD may also target reading problems in children with ADHD. While this study indicates that those reading problems are more likely to be related to reading comprehension, any problems with word reading may also be supported by interventions targeting executive dysfunction as this study finds that EF partially mediates the relations between ADHD and both types of reading skills.

Chapter 3. Exploring N-Back Cognitive Training for Children with ADHD.

Because children with ADHD typically demonstrate low levels of inhibitory control (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005), I tested the efficacy of n-back cognitive training for children with ADHD in a randomized controlled trial. Children with ADHD were trained on an n-back task, and their performance was compared with that of an active control group who were trained on a general knowledge and vocabulary task. The experimental group demonstrated transfer of training to a nontrained n-back task as well as to a measure of inhibitory control. These effects were correlated with the magnitude of training gains. The results suggest that n-back training may be useful in addressing some of the cognitive and behavioral issues associated with ADHD.

Chapter 4. Fostering Persistence among Children with ADHD: Can a Motivational Intervention Help?

Predominant theories of ADHD, such as the dual pathway model, suggest an underlying motivational impairment (Sonuga-Barke, 2002). This is thought to contribute to the characteristic tendency to endorse a fixed mindset and to demonstrate low self-efficacy, reduced persistence in response to challenge, and academic underachievement in children with ADHD (Dunn & Shapiro, 1999). Responding to these motivational challenges, I developed and pilot tested an intervention to investigate whether a set of small-group lessons could influence the mindset and persistence in children with ADHD as compared to a control intervention. Participants were randomly assigned to an experimental (motivation) or a control (study skills) intervention. Each included six 1-hour sessions: a pretest, four small-group lessons, and a posttest. The outcome measures included a mindset questionnaire and objective measures of persistence. Semi-structured focus groups with parents were included at follow up in order to better understand their experiences. Quantitative measures resulted in inconclusive findings, with both groups performing comparably at pre- and posttest, suggesting either that the intervention did not impact our outcome measures or that our measures were inadequate. Qualitative results from parent focus groups were more illuminating, suggesting that while participants from the study skills group acquired task-specific skills, many participants from the motivation intervention group reported improvements in self-efficacy. As such, qualitative findings indicate that each intervention may have had some of the intended effects.

Chapter 5: Concluding Remarks

The final chapter of this dissertation offers a summary of the studies and discusses major themes that emerged from them, including issues of heterogeneity within ADHD and the promise of parental interventions. It concludes with suggestions for future work.

References

Banaschewski, T., Roessner, V., Dittmann, R. W., Santosh, P. J., & Rothenberger, A. (2004). Non-stimulant medications in the treatment of ADHD. *European Child and Adolescent Psychiatry, Supplement*, *13*(1), 102–116. https://doi.org/10.1007/s00787-004-1010-x

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65–94. https://doi.org/10.1037/0033-2909.121.1.65

Barkley, R. A., Fischer, M., Smallish, L., & Fletcher, K. (2002). The persistence of attention-deficit/hyperactivity disorder into young adulthood as a function of reporting source and definition of disorder. *Journal of Abnormal Psychology*, *111*(2), 279–289. https://doi.org/10.1037/0021-843X.111.2.279

Beck, S. J., Hanson, C. a, Puffenberger, S. S., Benninger, K. L., & Benninger, W. B. (2010). A controlled trial of working memory training for children and adolescents with ADHD. *Journal of Clinical Child & Adolescent Psychology*, *39*(October 2010), 37–41. https://doi.org/10.1080/15374416.2010.517162

Biederman, Faraone, Keenan, Steingard, & Tsuang. (2001). Familial association between attention deficit disorder and anxiety disorders. *American Journal of Psychiatry*, *148*(2), 251–256.

Bigorra, A., Garolera, M., Guijarro, S., & Hervas, A. (2016). Long-term far-transfer effects of working memory training in children with ADHD: a randomized controlled trial. *European Child & Adolescent Psychiatry*, *25*(8), 853–867.

Bitsakou, P., Psychogiou, L., & Thompson, M. (2008). Inhibitory deficits in attention-deficit = hyperactivity disorder are independent of basic processing efficiency and IQ, 261–268.

https://doi.org/10.1007/s00702-007-0828-z

Cain, K. E. (2006). Individual differences in children's memory and reading comprehension: an investigation of semantic and inhibitory deficits. *Memory*, *14*(5), 553–569. https://doi.org/10.1080/09658210600624481

Carretti, B., Borella, E., Cornoldi, C., & De Beni, R. (2009). Role of working memory in explaining the performance of individuals with specific reading comprehension difficulties: A meta-analysis. *Learning and Individual Differences*, *19*(2), 246–251. https://doi.org/10.1016/j.lindif.2008.10.002

Carroll, J. M., Maughan, B., Goodman, R., & Meltzer, H. (2005). Literacy difficulties and psychiatric disorders: evidence for comorbidity. *Journal of Child Psychology and Psychiatry*, *46*(5), 524–532. https://doi.org/10.1111/j.1469-7610.2004.00366.x

Cartwright, K. (2015). Executive function and reading comprehension. In *Comprehension Instruction: Research-Based Best Practices* (3rd ed., p. 56).

Castellanos, F. X., Sonuga-Barke, E. J. S., Milham, M. P., & Tannock, R. (2006). Characterizing cognition in ADHD: Beyond executive dysfunction. *Trends in Cognitive Sciences*, *10*(3), 117–124. https://doi.org/10.1016/j.tics.2006.01.011

Chacko, A., Bedard, a. C., Marks, D. J., Feirsen, N., Uderman, J. Z., Chimiklis, A., … Ramon, M. (2014). A randomized clinical trial of Cogmed Working Memory Training in school-age children with ADHD: A replication in a diverse sample using a control condition. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *55*(3), 247–255. https://doi.org/10.1111/jcpp.12146

Chacko, A., Feirsen, N., Bedard, A.-C., Marks, D., Uderman, J. Z., & Chimiklis, A. (2013). Cogmed working memory training for youth with ADHD: A closer examination of efficacy utilizing evidence-based criteria. *Journal of Clinical Child & Adolescent Psychology*, *42*(May 2016), 769–783. https://doi.org/10.1080/15374416.2013.787622

Chhabildas, N., Pennington, B. F., & Willcutt, E. G. (2001). A comparison of the neuropsychological profiles of the DSM-IV subtypes of ADHD. *Journal of Abnormal Child Psychology*, *29*(6), 529–540. https://doi.org/10.1023/A:1012281226028

Cutting, L. E., Materek, A., Cole, C. A. S., Levine, T. M., & Mahone, M. E. (2009). Effects of fluency, oral language, and executive function on reading comprehension performance. *Annals of Dyslexia*, *59*, 34–54. https://doi.org/10.1007/s

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*(4), 450–466.

Dunn, P. B., & Shapiro, S. K. (1999). Gender differences in the achievement goal orientations of ADHD children. *Cognitive Therapy and Research*, *23*(3), 327–344. https://doi.org/10.1023/A:1018747716137

Dupaul, G. J., Gormley, M. J., & Laracy, S. D. (2013). Comorbidity of LD and ADHD: Implications of DSM-5 for assessment and treatment. *Journal of Learning Disabilities*, *46*(1), 43–51. https://doi.org/10.1177/0022219412464351

DuPaul, G., & Stoner, G. (2014). *ADHD in the schools* (3rd ed.). New York, New York, USA: Guilford Press.

Enge, S., Behnke, A., Fleischhauer, M., Küttler, L., Kliegel, M., & Strobel, A. (2014). No evidence for true training and transfer effects after inhibitory control training in young healthy adults. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *40*(4), 987–1001. https://doi.org/10.1037/a0036165

Fabiano, G. A., Pelham, W. E., Coles, E. K., Gnagy, E. M., Chronis-Tuscano, A., & O’Connor,

B. C. (2009). A meta-analysis of behavioral treatments for attention-deficit/hyperactivity disorder. *Clinical Psychology Review*, *29*(2), 129–140. https://doi.org/10.1016/j.cpr.2008.11.001

Faraone, S. V., Biederman, J., & Mick, E. (2005). The age-dependent decline of attention deficit hyperactivity disorder: a meta-analysis of follow-up studies. *Psychological Medicine*, *36*(02), 159. https://doi.org/10.1017/S003329170500471X

Frank, M. J. (2005). Dynamic dopamine modulation in the basal ganglia: A neurocomputational account of cognitive deficits in medicated and nonmedicated Parkinsonism. *Journal of Cognitive Neuroscience*, *17*(1), 51–72. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L40153377%5Cnhttp://dx.doi.org/10.1162/0898929052880093%5Cnhttp://sfx.bibl.ulaval.ca:9003/sfx_local?sid=EMBASE&issn=0898929X&id=doi:10.1162%2F0898929052880093&atitle=Dynamic+dopamine

Gernsbacher, M. A., & Faust, M. E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*(2), 245–262. https://doi.org/10.1037/0278-7393.17.2.245

Henderson, L., Snowling, M., & Clarke, P. (2013). Accessing, Integrating, and Inhibiting Word Meaning in Poor Comprehenders. *Scientific Studies of Reading*, *17*(3), 177–198. https://doi.org/10.1080/10888438.2011.652721

Hsu, N. S., Jaeggi, S. M., & Novick, J. M. (2017). A common neural hub resolves syntactic and non-syntactic conflict through cooperation with task-specific networks. *Brain and Language*, *166*, 63–77. https://doi.org/10.1016/j.bandl.2016.12.006

Huntington, D. D., & Bender, W. N. (1993). Adolescents with learning disabilities at risk?

Emotional well-being, depression, suicide. *Journal of Learning Disabilities*. https://doi.org/10.1177/002221949302600303

Ishii, T., Takahashi, O., Kawamura, Y., & Ohta, T. (2003). Comorbidity in attention deficit – hyperactivity disorder. *Osychiatry and Chilinical Neuroscience*, *57*, 457–463.

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Shah, P. (2011). Working memory training in typically developing children and children with Attention Deficit Hyperactivity Disorder: evidence for plasticity in executive control processes. In *Eighteenth Annual Cognitive Neuroscience Society Meeting*. San Francisco, CA.

Jones, M. R., Katz, B., Buschkuehl, M., Jaeggi, S. M., & Shah, P. (2018). Exploring n-back cognitive training for children with ADHD. *Journal of Attention Disorders*. https://doi.org/10.1177/1087054718779230

Kadesjö, B. (2000). Neuropsychiatric and neurodevelopmental disorders in a young school-age population. *Epidemiology and Comorbidity in a School Health Perspective*. Göteborg University, Göteborg.

Kendeou, P., Helder, A., Van den Broek, P., & Karlsson, J. (2014). A cognitive view of reading comprehension: Implications for reading difficulties. *Learning Disabilities Research and Practice*, *29*(February), 10–16. https://doi.org/10.1111/ldrp.12025

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlström, K., … Westerberg, H. (2005). Computerized training of working memory in children with ADHD: A randomized, controlled trial. *Journal of the American Academy of Child & Adolescent Psychiatry*, *44*, 177–186. https://doi.org/10.1097/00004583-200502000-00010

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology*, *24*(6), 781–791.

https://doi.org/10.1076/jcen.24.6.781.8395

Maniadaki, K., & Kakouros, E. (2017). *The complete guide to ADHD: Nature, diagnosis, and treatment*. Routledge.

Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *44*(4), 377–384. https://doi.org/10.1097/01.chi.0000153228.72591.73

Mezzacappa, E., & Buckner, J. C. (2010). Working memory training for children with attention problems or hyperactivity: a school-based pilot study. *School Mental Health*, *2*(4), 202–208. https://doi.org/10.1007/s12310-010-9030-9

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. https://doi.org/10.1006/cogp.1999.0734

Moffitt, T. E., Houts, R., Asherson, P., Belsky, D. W., Corcoran, D. L., Hammerle, M., … Caspi, A. (2015). Is adult ADHD a childhood-onset neurodevelopmental disorder? Evidence from a four-decade longitudinal cohort study. *American Journal of Psychiatry, 172*(10), 967–977. https://doi.org/10.1176/appi.ajp.2015.14101266

Nigg, J. T. (2005). Neuropsychologic theory and findings in Attention-Deficit/ Hyperactivity Disorder: The state of the field and salient challenges for the coming decade. *Bilingualism: Language and Cognition*, *57*, 1424–1435. https://doi.org/10.1016/j.biopsych.2004.11.011

Nigg, J. T., & Casey, B. J. (2005). Development and Psychopathology An integrative theory of attention - deficit / hyperactivity disorder based on the cognitive and affective neurosciences

An integrative theory of attention-deficit0 hyperactivity disorder based on the cognitive and affectiv. *Development and Psychopathology*, *17*, 785–806. https://doi.org/10.1017/S0954579405050376

Nigg, J. T., Willcutt, E. G., Doyle, A. E., & Sonuga-Barke, E. J. S. (2005). Causal heterogeneity in attention-deficit/hyperactivity disorder: Do we need neuropsychologically impaired subtypes? *Biological Psychiatry*, *57*(11), 1224–1230. https://doi.org/10.1016/j.biopsych.2004.08.025

Pastor, P. N., & Reuben, C. a. (2002). Attention deficit disorder and learning disability: United States, 1997-98. *Vital and Health Statistics. Series 10, Data from the National Health Survey*, 1–12.

Pelham, W. E., Smith, B. H., Evans, S. W., Bukstein, O., Gnagy, E. M., Greiner, A. R., & Sibley, M. H. (2017). The Effectiveness of Short- and Long-Acting Stimulant Medications for Adolescents With ADHD in a Naturalistic Secondary School Setting. *Journal of Attention Disorders*, *21*(1), 40–45. https://doi.org/10.1177/1087054712474688

Pennington, B. F. (2005). Commentary. Toward a new neuropsychological model of Attention-Deficity/Hyperactivity Disorder: Subtypes and multiple deficits. *Biological Psychiatry*, *57*(11), 1221–1223. https://doi.org/10.1016/j.biopysch.2005.03.010

Pennington, B. F., & Ozonoff, S. (1996). Executive Functions and Developmental Psychopathology, *37*(I), 51–87.

Polanczyk, G. V., Willcutt, E. G., Salum, G. A., Kieling, C., & Rohde, L. A. (2014). ADHD prevalence estimates across three decades: An updated systematic review and meta-regression analysis. *International Journal of Epidemiology*, *43*(2), 434–442. https://doi.org/10.1093/ije/dyt261

Roberts, G., Quach, J., Spencer-smith, M., Anderson, P. J., Gathercole, S., Gold, L., … Wake, M. (2016). Academic outcomes 2 years after working memory training for children with low working memory: a randomized clinical trial. *JAMA Pediatrics*, *170*(5), 1–10. https://doi.org/10.1001/jamapediatrics.2015.4568

Rubia, K., Alegria, A. A., Cubillo, A. I., Smith, A. B., Brammer, M. J., & Radua, J. (2014). Effects of stimulants on brain function in attention-deficit/hyperactivity disorder: A systematic review and meta-analysis. *Biological Psychiatry, 76*(8), 616–628. https://doi.org/10.1016/j.biopsych.2013.10.016

Sagvolden, T., Johansen, E. B., Aase, H., & Russell, V. A. (2005). The dynamic developmental theory of attention-deficit/hyperactivity disorder (ADHD): predominantly hyperactive/impulsive and combined subtypes. *Behavioral and Brain Sciences*, *28*, 397–468. https://doi.org/10.1017/S0140525X05430071

Schwartz, D. L., Cheng, K. M., Salehi, S., & Wieman, C. (2016). The half empty question for socio-cognitive interventions. *Journal of Educational Psychology*, *108*(3), 397–404. https://doi.org/10.1037/edu0000122

Sergeat, J. A., Oosterlaan, J., & van der Meere, J. (1999). Information processing and energetic factors in Attention-Deficit/Hyperactivity Disorder. In H. C. Quay & A. E. Hogan (Eds.), *Handbook of Disruptive Behavior Disorders* (Vol. 1, pp. 75–104). New York, New York, USA: Springer Science+Business Media.

Shavlev, L., Tsal, Y., & Mevorach, C. (2002). *Computerized progressive attentional training (CPAT) program: Effective direct intervention for children with ADHD. Dissertation*.

Shipstead, Z., Hicks, K. L., & Engle, R. W. (2012). Cogmed working memory training: Does the evidence support the claims? *Journal of Applied Research in Memory and Cognition*, *1*(3), 185–193. https://doi.org/10.1016/j.jarmac.2012.06.003

Sonuga-Barke, E. J. S., Taylor, E., Sembi, S., & Smith, J. (1992). Hyperactivity and delay aversion — I . The effect of delay on choice. *Journal of Psychology and Psychiatry*, *33*(2), 387–398.

Sonuga-Barke, E. J. S. (2002). Psychological heterogeneity in AD/HD — a dual pathway model of behaviour and cognition. *Behavioral Brain Research*, *130*, 29–36.

Sonuga-Barke, Edmund J. S. (1998). Categorical models of childhood disorder: A conceptual and empirical analysis. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *39*(1), 115–133. https://doi.org/10.1017/S0021963097001728

Sonuga-Barke, Edmund J.S., Brandeis, D., Coreste, S., Daley, D., Ferrin, M., Holtmann, M., … Coghill, D. (2013). Nonpharmacological Interventions for ADHD: Systematic Review and Meta-Analyses of Randomized Controlled Trials of Dietary and Psychological Treatments. *American Journal of Psychiatry*, (February 2016).

Sonuga-Barke, Edmund J.S., Dalen, L., & Remington, B. (2003). Do executive deficits and delay aversion make independent contributions to preschool attention-deficit/hyperactivity disorder symptoms? *Journal of the American Academy of Child and Adolescent Psychiatry*, *42*(11), 1335–1342. https://doi.org/10.1097/01.chi.0000087564.34977.21

Spencer, T. J. (2006). ADHD and Comorbidity in Childhood. *Journal of Psychiatry*, *67*, 27–31.

Toomey, S. L., Sox, C. M., Rusinak, D., & Finkelstein, J. a. (2012). Why do children with ADHD discontinue their medication? *Clinical Pediatrics*, *51*(8), 763–769. https://doi.org/10.1177/0009922812446744

Tripp, G., & Wickens, J. R. (2008). Research review: Dopamine transfer deficit: A neurobiological theory of altered reinforcement mechanisms in ADHD. *Journal of Child*

Psychology and Psychiatry, *49*(7), 691–704. https://doi.org/10.1111/j.1469-7610.2007.01851.x

Visser, S. N., Danielson, M. L., Bitsko, R. H., Holbrook, J. R., Kogan, M. D., Ghandour, R. M., … Blumberg, S. J. (2014). Trends in the parent-report of health care provider diagnosed and medicated ADHD: United States, 2003-2011. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*(1), 34–46. https://doi.org/10.1002/dev.21214.Developmental

Wåhlstedt, C., Thorell, L. B., & Bohlin, G. (2009). Heterogeneity in ADHD: Neuropsychological pathways, comorbidity and symptom domains. *Journal of Abnormal Child Psychology*, *37*(4), 551–564. https://doi.org/10.1007/s10802-008-9286-9

Willcutt, E. G., Pennington, B. F., Olson, R. K., Chhabildas, N., & Hulslander, J. (2005). Neuropsychological analyses of comorbidity between reading disability and Attention Deficit Hyperactivity Disorder: In search of the common deficit. *Developmental Neuropsychology*, *27*(1), 35–78. https://doi.org/10.1207/s15326942dn2701

Williams, J., & Dayan, P. (2005). Dopamine, learning, and impulsivity: A biological account of Attention-Deficit/Hyperactivity Disorder. *Journal of Child and Adolescent Psychopharmacology*, *15*(2), 160–179.

Wolraich, M., Brown, L., Brown, R., DuPaul, G., Earls, M., & Heidi, F. (2011). ADHD: Clinical practice guideline for the diagnosis, evaluation, and treatment of Attention-Deficit/Hyperactivity Disorder in children and adolescents. *American Academy of Pediatrics*, *128*(5), 1–16. https://doi.org/10.1542/peds.2011-2654

Zachor, D. A., Roberts, A. W., Bart Hodgens, J., Isaacs, J. S., & Merrick, J. (2006). Effects of long-term psychostimulant medication on growth of children with ADHD. *Research in Developmental Disabilities*, *27*(2), 162–174. https://doi.org/10.1016/j.ridd.2004.12.004

CHAPTER 2

The Relations among ADHD Symptoms, Reading Ability, and Executive Functioning

Attentional problems and reading problems appear to co-vary, with Attention Deficit Hyperactivity Disorder (ADHD) and Reading Disorders (RD) being co-diagnosed at rates of 10–40% (Pastor & Reuben, 2002). Low executive functioning (EF) is often present in children with ADHD and in children with RD, with some evidence suggesting a stronger link between low EF and reading comprehension problems as compared to word reading problems. In this study, we investigate whether the relation between attention and reading is more robust at the reading comprehension level or at the word reading level, and whether this association might be partially explained by variation in executive functioning (EF).

ADHD

ADHD is a commonly diagnosed developmental disorder characterized by inattention, hyperactivity, and impulsive behavior. Approximately 11% of US children have a history of ADHD diagnosis, and 9% of children have a current diagnosis of ADHD (Visser et al., 2014), though prevalence rates vary across studies (Moffitt et al., 2015; Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014). ADHD symptoms typically arise early in childhood (Visser et al., 2014) and continue through adolescence, and will persist into adulthood for 30–60% of individuals diagnosed (Barkley, 1997; Barkley, Fischer, Smallish, & Fletcher, 2002; Faraone, Biederman, & Mick, 2005; Matte et al., 2015; Moffit et al., 2015). Although a clinical diagnosis of ADHD is given when symptoms are judged to cause functional impairment (American Psychiatric Association, 2013), here we conceptualize ADHD symptoms on a continuum, as previous work has demonstrated that ADHD characteristics are distributed continuously in the general population (Levy, Hay, McStephen, Wood, & Waldman, 1997).

RD

Similarly, there is considerable variation in reading ability that appears to fall along a normal distribution, with some children excelling in literacy-related skills and others at the lower end of the continuum being diagnosed with RD (Shaywitz, Escobar, Shaywitz, Fletcher, & Makuch, 1992). RD is characterized by an impaired ability to read despite adequate instruction and normal levels of intelligence. While many factors contribute to successful reading, following the Simple View of Reading theory, the two primary skills are (1) decoding and encoding words (i.e., word reading), and (2) comprehending what those words mean (Hoover & Gough, 2009). RD can result from impairment in either one or both of these domains. Poor word-level or decoding skills can produce the classical symptoms of developmental dyslexia, such as difficulties with reading fluency and spelling (Shaywitz & Shaywitz, 2003). This RD subtype is not only the most widely recognized and diagnosed RD, but also the most common type of learning disability, with prevalence estimates ranging from 5 to 17.5% (Cutting et al., 2013).

Another RD subgroup includes children who struggle with reading comprehension despite adequate word-reading skills. This specific reading comprehension disorder (S-RCD) affects approximately 3–10% of school-aged children (Cutting et al., 2013). The S-RCD reader profile suggests that skills above and beyond word recognition contribute to reading comprehension ability (Cutting, Materek, Cole, Levine, & Mahone, 2009). Favoring this hypothesis is evidence demonstrating a link between reading comprehension and listening comprehension, which relies on oral language skills and domain-general processing abilities (EF). Listening comprehension has been shown to predict reading comprehension, and this association becomes significantly stronger once decoding skills have been mastered (Diakidoy, Stylianou, Karefillidou, & Papageorgiou, 2005). This finding indicates that reading comprehension relies primarily on the same domain-specific oral language and domain-general EF involved in listening comprehension (Sinatra, 1990; Kim & Phillips, 2014). Thus, if a reader has deficits in oral language or EF, he or she may be able to sound out words and even learn sight words, but will struggle to fully understand the text.

Executive Functioning

Many Individuals with ADHD and RD both demonstrate weaknesses in domain-general EF (Carretti, Borella, Cornoldi, & De Beni, 2009; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). EF, otherwise referred to as cognitive control, includes the range of higher-order mental processes that regulate cognition and support goal-directed behavior. According to Miyake and colleagues' (2000) model, there are three key EF skills: updating/working memory, shifting (attentional flexibility), and inhibitory control. Working memory involves the monitoring of information to be stored and manipulated in conscious thought. It is the ability to actively manage the items being attended to by replacing older, irrelevant, information with newer, more relevant information. Shifting is the ability to switch attention between tasks and adjust mental sets to meet changing demands and expectations. Inhibitory control encompasses the ability to purposefully inhibit dominant attentional and behavioral responses. This includes the ability to focus attention on relevant information in the face of competing, distracting information; it also refers to the capacity to override an impulsive or inappropriate response in favor of a more adaptive, but less natural response. While many studies investigate the relation between EF and reading by focusing on specific processes in EF, our study employs a global measure of EF that is intended to capture working memory, shifting, and inhibitory control as a single construct (Day & Connor, 2016).

EF and ADHD

Barkley's (1997) Executive Dysfunction model of ADHD, supported by meta-analytic evidence (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Willcut, Doyle, Nigg, Faraone,

& Pennington, 2005), argues that the primary impairment in ADHD is low EF, and that deficits in EF lead to impairments in the subsequent cognitive processes that rely upon it. This leads to the symptoms classically present in ADHD, such as a reduced ability to execute goal-directed responses or to persist on a task in the face of disruption (Barkley, 1997). However, ADHD is a heterogeneous disorder and some studies suggest that EF deficits are only present in approximately half of all individuals with ADHD (Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005). Thus, EF deficits do not fully explain the diversity of clinical presentation of ADHD across all cases.

Nonetheless, randomized control trials provide evidence corroborating the claim that EF deficits – at least among certain individuals – are causally linked to ADHD. In particular, Cogmed, an online working memory training program, has been used with participants who have ADHD and these individuals have demonstrated improvements in ADHD-related symptoms following training (Beck, Hanson, Puffenberger, Benninger, & Benninger, 2010; Klingberg et al., 2005; Klingberg, Forssberg, & Westerberg, 2002; Mezzacappa & Buckner, 2010). Programs targeting the working memory and inhibitory control dimensions of EF have also demonstrated some success in children with ADHD, including our adaptive n-back training. In that study, while the experimental and control groups exhibited similar levels of inhibitory control at pretest, the experimental group demonstrated significant improvements in non-trained working memory and inhibitory control tasks and reductions in parent-reported symptoms of ADHD that approached significance—both at posttest and at a 3-month delayed posttest (Jones, Katz, Buschkuehl, Jaeggi, & Shah, 2018; chapter 3). A similar study by Bigorra, Garolera, Guijarro, and Hervas (2016) found comparable effects. However, other EF training studies have failed to replicate these findings, leading to conflicting reviews and meta-analyses (Chacko et al., 2013; van der Donk, Hiemstra-Beernink, Tjeenk-Kalff, van der Leij, & Lindauer, 2015; Shipstead, Hicks, & Engle, 2012).

Together, the literature suggests that EF directly relates to the cognitive and behavioral symptoms of ADHD in some, but not all, individuals with ADHD.

EF in Reading

Given that EF is essential for performing complex tasks, it is not surprising that these cognitive skills are necessary for proficient reading processes. While some studies suggest that the relation between reading and EF does not vary as a function of types of reading (Peng et al., 2018), the contribution of EF to reading comprehension has been widely recognized, especially when students are reading more complex and longer texts, where reading strategies need to be utilized (Eason, Goldberg, Young, Geist, & Cutting, 2012). Indeed, the specific EF dimensions of working memory, shifting, and inhibitory control have been demonstrated to play important roles in reading comprehension (Cartwright, 2015; Kendeou, Helder, Van den Broek, & Karlsson, 2014; Yeniad, Malda, Mesman, Van Ijzendoorn, & Pieper, 2013). Working memory is essential for processing incoming information while keeping the prior information active and integrating these different pieces of information together (Daneman & Carpenter, 1980). Moreover, the ability to maintain information in working memory is important for inference making and monitoring one's comprehension. Inhibitory control allows the reader to suppress irrelevant information, while determining which information is relevant and to be maintained in working memory (Cain, 2006; Henderson, Snowling, & Clarke, 2013). Therefore, inhibitory control is also an important component necessary for good comprehension skills (Gernsbacher & Faust, 1991). Finally, the ability to shift between concepts is critical in order to select and maintain appropriate strategies and disengagement from irrelevant ones (Yeniad et al., 2013). Consequently, weaknesses in EF can reduce the reader's ability to effectively comprehend complex texts.

Some experimental work corroborates this evidence. In a study by Loosli, Buschkuehl, Perrig, & Jaeggi (2011), students who participated in working memory training demonstrated improvements on reading measures. These results indicate that working memory may, in fact, have a causal relationship to reading skills. Furthermore, the greatest gains in reading skills following training were found in reading comprehension, as compared to word reading. A similar study by Karbach, Strobach, & Schubert (2015) also found improvements on a global measure of reading following working memory training, and Peng & Fuchs (2017) found improvements in listening comprehension following working memory training. However, other studies failed to find transfer from working memory training to reading (Jacob & Parkinson, 2015; Melby-Lervåg & Hulme, 2013), indicating that further work is needed in this area.

EF in RD

While an extensive body of literature has linked EF skills to reading comprehension, fewer studies have explored the mechanisms underlying deficits in reading comprehension between distinct reader profiles (Locascio, Mahone, Eason, & Cutting, 2010). It is argued that children with general RD experience a "processing bottleneck" as deficiencies in word recognition place demands on higher-order cognition that limit the availability of these skills for reading comprehension. However, the bottleneck processing theory cannot fully account for S-RCD, suggesting that S-RCD may be related to weaknesses in the higher-level, domain-general EF (Cutting et al., 2009).

Available research literature supports the unique contribution of EF to S-RCD. In an investigation of the role of EF in reading processes, working memory was significantly related to reading comprehension, even after accounting for other well-known contributors such as fluency and vocabulary. Conversely, EF skills did not predict word-reading performance (Sesma, Mahone, Levine, Eason, & Cutting, 2009). A follow-up study by Cutting and colleagues (2009) demonstrated that children with S-RCD show similar word recognition and decoding skills as their typically developing peers; yet, they exhibit strikingly lower EF abilities than both children with general RD and typically developing children, with no significant differences between the latter two groups. While some research has found EF deficits in children with dyslexia or general RD, this impairment seems to be explained by overall weaknesses in phonological processing (Locascio et al., 2010). Ultimately, EF skills consistently appear to be impaired in S-RCD (Cutting et al., 2009; Locascio et al., 2010), suggesting that shortfalls in domain general processes underlie reading comprehension failure.

Relations among EF, ADHD, and RD

Given the shared EF deficits amongst most children with ADHD and RD, it is possible that EF impairments account for the some of the high rates of comorbid diagnoses between these disorders. More specifically, the EF weaknesses present in ADHD may contribute to reading comprehension challenges. Favoring this hypothesis, prior research has shown that children with ADHD demonstrate listening comprehension deficits even in the absence of language impairments, and that these comprehension problems still remain after controlling for children's word decoding abilities (McInnes, Humphries, Hogg-Johnson, & Tannock, 2003). The purpose of the present study is to extend this line of research to reading processes, because it not clear whether RD diagnosed along with ADHD is more commonly indicative of word reading or comprehension problems. Specifically, the present study examines the relations among ADHD inattentive symptoms, word reading, and reading comprehension.

We focused our assessment of ADHD to inattention problems for two reasons. First, prior research demonstrates the link between RD and ADHD is more robust for inattentive symptoms than for hyperactive/impulsive symptoms (Willcutt & Pennington, 2000). Children with ADHD-predominantly inattentive type (ADHD-IA) are also more likely than their peers with ADHD-combined type (ADHD-C) to be diagnosed with learning disabilities, receive speech and language services, and show greater academic impairment (Weiss, Worling, & Wasdell, 2003). Moreover, Warner-Rogers, Taylor, Taylor, & Sandberg (2000) found that children with ADHD-IA exhibit more deficits in reading accuracy and comprehension compared to typically developing peers, whereas children with ADHD-C do not significantly differ from controls in their reading abilities. The second reason we assess inattentive symptoms is evidence suggesting that EF impairments are more pronounced in ADHD-IA than ADHD-C. Chhabildas, Pennington, & Willcutt, (2001) suggest that low inhibitory control is characteristic of children with ADHD-IA, but not those with ADHD-C; similar studies find that inhibition deficits are independently related to inattentive symptoms and not hyperactive/impulsive symptoms (Thorell, 2007; Wåhlstedt, 2009).

Hence, we examined the relations among ADHD inattention symptoms, word reading, and reading comprehension to test whether ADHD symptoms are more highly correlated with comprehension skills than with word reading skills. This investigation is relevant not only for those diagnosed with ADHD or RD. Clearly, there is an association between attentional skills and reading ability, and better understanding this relation may be beneficial to all students who vary in these capacities.

To investigate this association between ADHD symptoms and reading ability we ask the following questions: (1) Are ADHD symptoms more strongly associated with reading comprehension or with word reading ability? And (2) does EF (working memory, flexibility, and inhibitory control) mediate the relation between ADHD symptoms and reading comprehension? Taking a dimensional approach to ADHD symptoms and reading ability, we will answer these questions by analyzing data from a large community sample of 5^{th} grade students for whom data were available on ADHD symptoms, reading comprehension, word reading, and EF. We hypothesize that ADHD symptoms will be more strongly associated with reading comprehension than with word reading ability and that EF will partially mediate the relation between ADHD symptoms and reading comprehension but not ADHD symptoms and word reading. We do not hypothesize a full mediation as we know that ADHD symptoms and reading problems reflect complex etiologies that cannot be fully explained by low EF alone.

Methods

Participants

Data were collected from 427 fifth grade students in 27 classrooms in six Florida schools. Forty one students were excluded due to missing data on all variables of interest for this study. The final sample included 387 participants from 26 classrooms. All classrooms and schools from the original sample were still represented in the final sample with the exception of one classroom, in which all data were missing from all measures of interest. Participants were 49% female. Forty-seven percent of the participants identified themselves as White, 42% as Black or African-American, 5% as Asian, 4% as Hispanic, and 2% as biracial or other. Twenty-seven percent of the participants qualified for free- or reduced-price lunch. These participants were recruited as part of a larger study aimed at investigating the efficacy of an individualized literacy instruction program (Connor, Morrison, Fishman, Schatschneider, & Underwood, 2007; Connor et al., 2014)**.** Fifth graders were chosen from a larger sample of first graders through fifth graders as 10 is the approximate age at which differentiation between comprehension measures and decoding measures becomes more clear, because the increasing mastery of decoding results in the performance on measures of reading comprehension to be less limited by decoding skills (Lonigan, Burgess, & Schatschneider, 2018).

Measures

Table 2.1 provides the descriptive statistics for all measures. Table 2.2 provides the correlations among those measures.

Table 2.1

Descriptive Statistics for All Measures

Measure	N	Minimum	Maximum	Mean	Standard Deviation
ADHD symptoms	298	1	7	4.49	1.47
EF	309	1	10	7.87	1.97
Word Reading W-Scores	370	453	563	520.78	16.55
Word Reading Standard Scores	370	68	137	105.60	11.13
Reading Comprehension W-Scores	370	465	544	504.79	11.63
Reading Comprehension Standard Scores	370	64	141	89.74	11.01

Table 2.2

Pearson Correlations among All Measures

Measure	ADHD symptoms	EF	Word Reading	Reading Comprehension
ADHD symptoms	1			
EF	0.32	1		
Word Reading W-Scores	0.43	0.39	1	
Reading Comprehension W-Scores	0.52	0.42	0.65	1

Note: All correlations are significant at the 0.01 level (2-tailed).

ADHD Symptoms. ADHD Symptoms were measured using a subscale of the Strengths and Weaknesses of ADHD-symptoms and Normal-behavior (SWAN) Scale (Swanson et al., 2012). The attention deficit subscale consists of 9 items measuring the full range of attentional skills in the general population rather than only pathological signs and symptoms of ADHD ($\alpha = 0.91$ for the full scale, Lakes, Swanson, & Riggs, 2012; $\alpha = 0.98$ for the subscale in our sample). This approach moves beyond a categorical concept of ADHD to a more dimensional approach. Teachers are asked to score their students by comparing them to other children of the same age on skills such as paying attention to instructions and details, maintaining focus in the face of distraction, and sustaining engagement on tasks that require prolonged mental effort. The items are rated on a seven-point scale with 4 being average, 7 being far above average, and 1 being far below average, indicating the presence of an ADHD trait measured by that item. The dependent measure was the average score across items, where a lower score indicates more ADHD symptoms.

Executive Functioning Executive functioning was measured using the Remembering Rules and Regulation Picture Task, designed to measure working memory, shifting, and inhibitory control (RRRP; $\alpha = 0.97$; Day & Connor, 2016; $\alpha = 0.66$ in our sample). In this task, children are asked to place different colored blocks on objects in a picture of a park. They must attend to the order of the instructions, the colors of the blocks, the locations of the blocks. They must also wait to place any blocks until after the tester says "go." There are ten questions in total. In the second portion of the task (questions 6–10), children must also switch blue blocks for red blocks and red blocks for blue blocks, introducing an additional load on working memory and inhibitory control. We used the scores from the second half of this task as our measure of EF. This score is highly correlated with digit span reverse task in previous work (Day & Connor, 2016).

Word Reading. Word reading skills were measured using the Letter-Word Identification subtest of the Woodcock Johnson III ($\alpha = 0.91$; Woodcock, McGrew, & Mather, 2003), which assesses a participant's ability to decode words in isolation. In this task, participants read a list of words that are arranged in order of increasing difficulty. The test concludes when a participant fails to correctly answer seven consecutive questions within a set. This test produces standard scores, which describe a student's performance relative to average performance, where average is 100 with a standard deviation of 15. In addition to standard scores, each participant earns a W-Score (which we use as the dependent variable for analyses). This score is on a standardized scale, similar to a Rasch scale score, with a mean of 500 (a typical 9 year old) and a standard deviation of 15, making it directly comparable to other Woodcock Johnson III scales.

Reading Comprehension. Reading comprehension was measured using the Passage Comprehension subtest of the Woodcock Johnson III, which assesses each participant's reading comprehension ($\alpha = 0.83$; Woodcock, McGrew, & Mather, 2003). In this task, participants read progressively more challenging passages and answer questions about them. The test concludes when a participant fails to correctly answer seven consecutive questions within a set. This scale also provides standard scores and standardized W-Scores for direct comparison to other scales. W-Scores served as the dependent variable.

Procedure

In the spring, teachers were asked to rate their students on their ADHD symptoms using the SWAN scale. Students completed multiple assessments as part of the larger study at the beginning, middle, and end of the school year. These included the measures of interest here: the RRRP, the Letter-Word Identification subtest, and the Passage Comprehension subtest of the

Woodcock Johnson III. Students were assessed in a quiet area at their school. Spring scores were used for all measures for this study.

Missing Data

The data include a complex pattern of missing data. Of the 387 participants in 5th grade, 89 (23%) had missing data on the SWAN, 78 (20%) had missing data on the RRRP, and 17 had missing data on reading measures (4%). We conducted *t*-tests of the key constructs to diagnose the missing data mechanism. The students with missing data on the SWAN tended to have higher word reading (t=3.90, p<.001) and reading comprehension (t=2.90, p=.004), whereas the students with missing data on the RRRP had lower word reading (t=3.00, p=.003). This indicates that the pattern of missing data is likely to be missing at random (MAR; not missing completely at random; MCAR), as there appears to be a systematic association between the likelihood of missing values and the observed data. As such, list-wise deletion would introduce bias. To account for this missing data mechanism, we used restricted-maximum likelihood (REML) to produce asymptotically unbiased estimates, as REML produces more accurate posterior variances when level-2 units are small (Raudenbush & Bryk, 2002). Although assumptions of missing at random cannot be confirmed statistically, we must rely on its substantive reasonableness (Little & Rubin, 2002).

Analysis Plan

Due to the hierarchical structure of our data, with students nested in classrooms, we used Hierarchical Linear Modeling (HLM; Raudenbush & Bryk, 2002). An unconditional model was estimated with ADHD symptoms as the outcome variable $ADHD\ Attention\ Symptoms_{ij} = \gamma_{00} + u_{0j} + r_{ij}$). First, the relations among ADHD symptoms, word reading, and comprehension was estimated with the following equation: $ADHD\ Attention\ Symptoms_{ij} = \gamma_{00} + \gamma_{10}*Word\ Reading_{ij} + \gamma_{20}*Comprehension_{ij} + u_{0j} + r_{ij}$. A general linear hypothesis test (χ^2) was conducted to examine whether the strength of the association between reading comprehension and ADHD attention symptoms was significantly stronger than that between word reading and ADHD symptoms. Finally, a mediation model was constructed, which included our measure of EF: *ADHD Attention* $Symptoms_{ij} = \gamma_{00} + \gamma_{10}{*}EF_{ij} + \gamma_{20}{*}Word\ Reading_{ij} + \gamma_{30}{*}Comprehension_{ij} + u_{0j} + r_{ij}.$

Results

The unconditional model had an inter-class correlation of 0.15. This indicates that 15% of the variance in ADHD attention symptoms could be accounted for by classroom differences. As such, the use of HLM is warranted to account for variances at different hierarchical levels. In model 1, ADHD attention symptoms were significantly predicted by word reading (b = 0.013, p = 0.002) and reading comprehension (b = 0.053, p<0.001). Standardizing these coefficients, a one standard deviation increase in word reading was associated with a 0.15 standard deviation increase in ADHD symptoms, whereas a one standard deviation increase in reading comprehension was associated with a 0.45 standard deviation increase in ADHD attention symptoms (with a higher score indicating fewer symptoms). The general linear hypothesis test was significant (χ^2 (1, N = 281) = 61.97, p <0.001), supporting our hypothesis that the strength of the association between reading comprehension and ADHD symptoms was significantly stronger than that between word reading and ADHD symptoms.

Finally, a mediation model was constructed, which included our measure of EF. The relation between EF and ADHD attention symptoms was significant (b = 0.08, p = 0.03). In standardized units, a one standard deviation increase in EF was associated a modest 0.12 standard deviation increase in ADHD symptom scores (where a higher ADHD symptom score indicates fewer symptoms). Furthermore, the link between reading comprehension and ADHD attention symptoms was partially mediated by EF. Though the direct effect between reading comprehension and ADHD attention symptoms remained significant (*b* = 0.049, *p*< 0.001), the magnitude of the coefficient was reduced from 0.054 to 0.049. Meanwhile, the relation between word reading and ADHD attention symptoms was also slightly reduced (*b* = 0.012, *p* = 0.007).

Table 4.3
HLM Model 1

	Coefficient	Standard Error	Degrees of Freedom	χ^2	*p*-value
Intercept	-29.273	3.820	24		<0.001
Word Reading	0.013	0.004	270		0.002
Reading Comprehension	0.054	0.009	270		<0.001
	Standard Deviation	**Variance Component**	**Degrees of Freedom**	**χ^2**	***p*-value**
Level-2 (Classroom) Variance	0.436	0.190	24	61.972	<0.001
Level-1 (Student) Variance	1.171	1.371			

Note: Outcome is ADHD Symptoms. Coefficients are unstandardized.

Table 4.4
HLM Mediation Model

	Coefficient	Standard Error	Degrees of Freedom	χ^2	*p*-value
Intercept	-26.825	3.673	24		<0.001
Word Reading	0.012	0.004	268		0.007
Reading Comprehension	0.049	0.009	268		<0.001
Executive Functioning	0.076	0.034	268		0.026
	Standard Deviation	**Variance Component**	**Degrees of Freedom**	**χ^2**	***p*-value**
Level-2 (Classroom) Variance	0.423	0.179	24	59.031	<0.001
Level-1 (Student) Variance	1.168	1.364			

Note: Outcome is ADHD Symptoms. Coefficients are unstandardized.

Discussion

Attentional control and reading skills in the general population appear to be normally distributed, with symptoms of ADHD and RD appearing at the low end of the continuum (Levy, Hay, McStephen, Wood, & Waldman, 1997; Shaywitz, Escobar, Shaywitz, Fletcher, & Makuch, 1992). With co-diagnoses of ADHD and RD reported between 10–40% (Pastor & Reuben, 2002), it is important to understand the nature of the association between attentional control and reading ability. This study addresses the issue by asking two questions. The first was whether inattentive symptoms of ADHD are more closely related to reading comprehension or to word reading skills. This is important in developing a more nuanced theoretical understanding of how ADHD relates to reading challenges, and for providing evidence-based recommendations to teachers of children with ADHD or attentional problems. The second question was whether EF explains any of the relations among ADHD symptoms and reading comprehension. Understanding shared etiology would contribute to our theoretical understanding of co-morbidity in ADHD and RD, and might result in the development of interventions that are able to effectively target both ADHD symptoms and reading ability. While this study cannot provide causal evidence of etiology, correlational data can serve a first step in that direction.

We narrowed our assessment of ADHD to attentional problems as prior research suggests that reading difficulties are more strongly associated with symptoms of inattention than symptoms of hyperactivity (Willcutt & Pennington, 2000). Additionally, other studies have found that EF impairments are more pronounced with inattentive symptoms compared to hyperactive/impulsive symptoms (Thorell, 2007). We hypothesized that the association between ADHD symptoms and reading comprehension would be stronger than that between ADHD symptoms and word reading, and we hypothesized that EF would partially mediate the relation between ADHD symptoms and reading comprehension.

Consistent with our hypotheses, we found indeed that students' ADHD symptoms were more predictive of reading comprehension (coefficient = 0.05) than of word reading (coefficient = 0.01), keeping in mind that both assessments were on the same scale (W-score). In fact, a one standard deviation increase in word reading was associated with a 0.15 standard deviation increase in ADHD symptoms, whereas a one standard deviation increase in reading comprehension was associated with a 0.45 standard deviation increase in ADHD attention symptoms (with a higher score indicating fewer symptoms). Further supporting our hypotheses, the association between ADHD symptoms and reading comprehension was partially mediated by EF. That is, a small part of the association between ADHD symptoms and reading comprehension can be explained by students' EF.

We also found that EF explained a small amount of variance in the association between ADHD symptoms and word reading. In the present study, children's word reading abilities were measured using the Letter-Word Identification subtest of the Woodcock Johnson III, on which they were asked to read a list of words of increasing difficulty. While many of the initial words were likely familiar to 5th grade students and could be automatically identified, the more advanced words were pulled from vocabulary that represented a seventh grade to adult reading level. Thus, students had to engage their EF skills in order to accurately decode difficult, unfamiliar words such as "therapeutic" and "aeronautic." Such a task might be particularly challenging for students with low EF abilities. This difficulty may occur when a reader encounters a word he or she does not automatically recognize, thus the reading process is slowed down and more effort is required for the reader to remember and apply the "print-to-sound" rules to this new word. Simply put, the reader must use his or her EF skills in order to accurately decode an unfamiliar word (Samuels, 1988). Thus, although we did not specifically hypothesize that the link between ADHD symptoms and word reading would be mediated by EF or that the relation itself might be as strong as that between ADHD symptoms and reading comprehension, the finding is not altogether surprising.

Limitations

A potential limitation of this work, as it relates to clinical implications, is that our data are drawn from a community sample and not from a clinical sample. Future research attempting to make clinical recommendations should replicate this work with children who have been diagnosed with ADHD and/or different subtypes of RD. However, we consider it important to address the general associations among attention symptoms, reading ability, and EF as well, as these abilities are normally distributed in the general population (Levy, Hay, McStephen, Wood, & Waldman, 1997; Shaywitz, Escobar, Shaywitz, Fletcher, & Makuch, 1992). An additional limitation inherent to this type of work is the correlational nature of our data. Causal conclusions cannot be drawn from these findings. Furthermore, the children in our sample are all fifth graders. Considering that ADHD and RD are developmental disorders, that reading skills change drastically during early development, and that the relations between EF and reading comprehension change through development (Peng et al., 2018), it is possible that our findings would present differently at other points in development. Our measure of EF also suffered from rather low reliability ($\alpha = 0.66$). The reliability from the original sample (third graders) was much higher, which may reflect the relative age-appropriateness of the task. Additionally, as a global measure of EF, the RRRP lacked specificity that could be potentially useful in understanding how various EF processes relate to ADHD symptoms and reading ability. Future work should employ multiple robust measures per construct to reduce the risk that findings reflect task-specific error, and should include EF measures that isolate working memory, shifting, and inhibitory control.

Implications

A practical implication from this study is that educators and professionals working with children who have ADHD or who struggle with attention problems more generally should also closely examine their students' component reading skills. We found that ADHD symptoms were associated with word reading and reading comprehension, but more strongly associated with reading comprehension. This suggests that students with ADHD or who have attentional problems should be screened for both types of reading, so that reading instruction can be intentionally tailored to meet their unique learning needs. Additional implications for these results include the potential for EF interventions that target the EF skills implicated in both reading comprehension and word reading (e.g., Loosli et al., 2011; Jones et al., 2018). Ultimately, these findings are a step toward developing a more nuanced understanding of the relations between ADHD symptoms and reading difficulties.

References

Acock, A. C. (2013). *Discovering Structural Equation Modeling Using Stata: Revised Edition*. Stata Press.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing

American Psychiatric Association. (2014). *Diagnostic and statistical manual of mental disorders : DSM-5. American Psychiatric Association*. *DSM*. https://doi.org/10.1176/appi.books.9780890425596.744053

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65–94. https://doi.org/10.1037/0033-2909.121.1.65

Barkley, R. A., Fischer, M., Smallish, L., & Fletcher, K. (2002). The persistence of attention-deficit/hyperactivity disorder into young adulthood as a function of reporting source and definition of disorder. *Journal of Abnormal Psychology*, *111*(2), 279–289. https://doi.org/10.1037/0021-843X.111.2.279

Beck, S. J., Hanson, C. a, Puffenberger, S. S., Benninger, K. L., & Benninger, W. B. (2010). A controlled trial of working memory training for children and adolescents with ADHD. *Journal of Clinical Child & Adolescent Psychology*, *39*(October 2010), 37–41. https://doi.org/10.1080/15374416.2010.517162

Bigorra, A., Garolera, M., Guijarro, S., & Hervas, A. (2016). Long-term far-transfer effects of working memory training in children with ADHD: a randomized controlled trial. *European Child & Adolescent Psychiatry*, *25*(8), 853–867.

Cain, K. E. (2006). Individual differences in children’s memory and reading comprehension: an investigation of semantic and inhibitory deficits. *Memory*, *14*(5), 553–569. https://doi.org/10.1080/09658210600624481

Carretti, B., Borella, E., Cornoldi, C., & De Beni, R. (2009). Role of working memory in explaining the performance of individuals with specific reading comprehension difficulties: A meta-analysis. *Learning and Individual Differences*, *19*(2), 246–251. https://doi.org/10.1016/j.lindif.2008.10.002

Cartwright, K. (2015). Executive function and reading comprehension. In *Comprehension Instruction: Research-Based Best Practices* (3rd ed., p. 56).

Chacko, A., Feirsen, N., Bedard, A.-C., Marks, D., Uderman, J. Z., & Chimiklis, A. (2013). Cogmed working memory training for youth with ADHD: A closer examination of efficacy utilizing evidence-based criteria. *Journal of Clinical Child & Adolescent Psychology*, *42*(May 2016), 769–783. https://doi.org/10.1080/15374416.2013.787622

Chhabildas, N., Pennington, B. F., & Willcutt, E. G. (2001). A comparison of the neuropsychological profiles of the DSM-IV subtypes of ADHD. *Journal of Abnormal Child Psychology*, *29*(6), 529–540. https://doi.org/10.1023/A:1012281226028

Connor, C. M., Morrison, F. J., Fishman, B. J., Schatschneider, C., & Underwood, P. (2007). Algorithm-Guided Individualized Reading Instruction. *Science, 315*, 464–465. https://doi.org/10.1126/science.1134513

Connor, C. M., Spencer, M., Day, S. L., Ingebrand, S. W., McLean, L., & Morrison, F. J. (2014). Capturing the complexity: Content, type, and amount of instruction and quality of the classroom learning environment synergistically predict third graders’ vocabulary and reading comprehension outcomes. *Journal of Educational Psychology*, *106*(3), 762–778. https://doi.org/10.1037/a0035921.Capturing

Cutting, L. E., Clements-Stephens, A., Pugh, K. R., Burns, S., Cao, A., Pekar, J. J., … Rimrodt, S. L. (2013). Not all reading disabilities are dyslexia: distinct neurobiology of specific comprehension deficits. *Brain Connectivity*, *3*(2), 199–211. https://doi.org/10.1089/brain.2012.0116

Cutting, L. E., Materek, A., Cole, C. A. S., Levine, T. M., & Mahone, M. E. (2009). Effects of fluency, oral language, and executive function on reading comprehension performance. *Annals of Dyslexia*, *59*, 34–54. https://doi.org/10.1007/s

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*(4), 450–466.

Day, S. L., & Connor, C. M. (2016). Examining the Relations Between Self-Regulation and Achievement in Third-Grade Students. *Assessment for Effective Intervention*, 1–13. https://doi.org/10.1177/1534508416670367

Diakidoy, I. A. N., Stylianou, P., Karefillidou, C., & Papageorgiou, P. (2005). The relationship between listening and reading comprehension of different types of text at increasing grade levels. *Reading Psychology*, *26*(1), 55–80. https://doi.org/10.1080/02702710590910584

Eason, S. H., Goldberg, L. F., Young, K. M., Geist, M. C., & Cutting, L. E. (2012). Reader-text interactions: How differential text and question types influence cognitive skills needed for reading comprehension. *Journal of Educational Psychology*, *104*(3), 515–528. https://doi.org/10.1037/a0027182

Faraone, S. V., Biederman, J., & Mick, E. (2005). The age-dependent decline of attention deficit hyperactivity disorder: a meta-analysis of follow-up studies. *Psychological Medicine*, *36*(02), 159. https://doi.org/10.1017/S003329170500471X

Gernsbacher, M. A., & Faust, M. E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*(2), 245–262. https://doi.org/10.1037/0278-7393.17.2.245

Henderson, L., Snowling, M., & Clarke, P. (2013). Accessing, Integrating, and Inhibiting Word Meaning in Poor Comprehenders. *Scientific Studies of Reading*, *17*(3), 177–198. https://doi.org/10.1080/10888438.2011.652721

Hoover, W. A., & Gough, P. B. (2009). The simple view of reading. *ITE English: Readings for Discussion*, Pg. 3. Retrieved from http://www.ite.org.uk/ite_readings/simple_view_reading.pdf

Jacob, R., & Parkinson, J. (2015). The potential for school-based interventions that target executive function to improve academic achievement. *Review of Educational Research*, *85*(4), 512–552. https://doi.org/10.3102/0034654314561338

Jones, M. R., Katz, B., Buschkuehl, M., Jaeggi, S. M., & Shah, P. (2018). Exploring n-back cognitive training for children with ADHD. *Journal of Attention Disorders*. https://doi.org/10.1177/1087054718779230

Karbach, J., Strobach, T., & Schubert, T. (2015). Adaptive working-memory training benefits reading, but not mathematics in middle childhood. *Child Neuropsychology*, *21*(3), 285–301. https://doi.org/10.1080/09297049.2014.899336

Kendeou, P., Helder, A., Van den Broek, P., & Karlsson, J. (2014). A cognitive view of reading comprehension: Implications for reading difficulties. *Learning Disabilities Research and Practice*, *29*(February), 10–16. https://doi.org/10.1111/ldrp.12025

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlström, K., … Westerberg, H. (2005). Computerized training of working memory in children with ADHD: A randomized, controlled trial. *Journal of the American Academy of Child & Adolescent*

Psychiatry, *44*, 177–186. https://doi.org/10.1097/00004583-200502000-00010

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology*, *24*(6), 781–791. https://doi.org/10.1076/jcen.24.6.781.8395

Lakes, K. D., Swanson, J. M., & Riggs, M. (2012). The reliability and validity of the English and Spanish Strengths and Weaknesses of ADHD and Normal Behavior Rating Scales in a preschool sample: Continuum measures of hyperactivity and inattention. *Journal of Attention Disorders*, *16*(6), 510–516. https://doi.org/10.1177/1087054711413550

Levy, F., Hay, D. A., McStephen, M., Wood, C., & Waldman, I. (1997). Attention-deficit hyperactivity disorder: A category or a continuum? Genetic analysis of a large-scale twin study. *Journal of the American Academy of Child and Adolescent Psychiatry*, *36*(6), 737–744. https://doi.org/10.1097/00004583-199706000-00009

Little, R. J., & Rubin, D. B. (2002). *Statistical analysis with missing data*. New York, New York, USA: Wiley.

Locascio, G., Mahone, E. M., Eason, S. H., & Cutting, L. E. (2010). Executive dysfunction among children with reading comprehension deficits. *Journal of Learning Disabilities*, *43*(5), 441–454. https://doi.org/10.1177/0022219409355476

Lonigan, C. J., Burgess, S. R., & Schatschneider, C. (2018). Examining the simple view of reading with elementary school children: Still simple after all these years. *Remedial and Special Education*, *39*(5), 260–273. https://doi.org/10.1177/0741932518764833

Loosli, S. V, Buschkuehl, M., Perrig, W. J., & Jaeggi, S. M. (2011). Working memory training improves reading processes in typically developing children. *Child Neuropsychology*, *18*(1), 62–78. https://doi.org/10.1080/09297049.2011.575772

Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *44*(4), 377–384. https://doi.org/10.1097/01.chi.0000153228.72591.73

McInnes, A., Humphries, T., Hogg-Johnson, S., & Tannock, R. (2003). Listening comprehension and working memory are impaired in Attention-Deficit Hyperactivity Disorder irrespective of language impairment. *Journal of Abnormal Child Psychology*, *31*(4), 427–443.

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, *49*(2), 270–291. https://doi.org/10.1037/a0028228

Mezzacappa, E., & Buckner, J. C. (2010). Working memory training for children with attention problems or hyperactivity: a school-based pilot study. *School Mental Health*, *2*(4), 202–208. https://doi.org/10.1007/s12310-010-9030-9

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. https://doi.org/10.1006/cogp.1999.0734

Moffitt, T. E., Houts, R., Asherson, P., Belsky, D. W., Corcoran, D. L., Hammerle, M., … Caspi, A. (2015). Is adult ADHD a childhood-onset neurodevelopmental disorder? Evidence from a four-decade longitudinal cohort study. *American Journal of Psychiatry*, *172*(10), 967–977. https://doi.org/10.1176/appi.ajp.2015.14101266

Nigg, J. T., Willcutt, E. G., Doyle, A. E., & Sonuga-Barke, E. J. S. (2005). Causal heterogeneity in attention-deficit/hyperactivity disorder: Do we need neuropsychologically impaired subtypes? *Biological Psychiatry*, *57*(11), 1224–1230.

https://doi.org/10.1016/j.biopsych.2004.08.025

Pastor, P. N., & Reuben, C. a. (2002). Attention deficit disorder and learning disability: United States, 1997-98. *Vital and Health Statistics. Series 10, Data from the National Health Survey*, 1–12.

Peng, P., Barnes, M., Wang, C. C., Wang, W., Li, S., Swanson, H. L., … Tao, S. (2018). Meta-analysis on the relation between reading and working memory. *Psychological Bulletin*, *144*(1), 48–76. https://doi.org/10.1037/bul0000124

Peng, P., & Fuchs, D. (2017). A randomized control trial of working memory training with and without strategy instruction: Effects on young children's working memory and comprehension. *Journal of Learning Disabilities*, *50*(1), 62–80. https://doi.org/10.1177/0022219415594609

Polanczyk, G. V., Willcutt, E. G., Salum, G. A., Kieling, C., & Rohde, L. A. (2014). ADHD prevalence estimates across three decades: An updated systematic review and meta-regression analysis. *International Journal of Epidemiology*, *43*(2), 434–442. https://doi.org/10.1093/ije/dyt261

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical Linear Models: Applications and Data Analysis Methods*. *Advanced quantitative techniques in the social sciences 1* (Vol. 2nd).

Sesma, H. W., Mahone, E. M., Levine, T., Eason, S. H., & Cutting, L. E. (2009). The contribution of executive skills to reading comprehension. *Child Neuropsychology : A Journal on Normal and Abnormal Development in Childhood and Adolescence*, *15*(3), 232–246. https://doi.org/10.1080/09297040802220029

Shaywitz, S. E., & Shaywitz, B. a. (2003). Dyslexia (specific reading disability). *Pediatrics in Review*, *24*(5), 147–153. https://doi.org/10.1542/pir.24-5-147

Shaywitz, Sally E., Escobar, M. D., Shaywitz, B. A., Fletcher, J. M., & Makuch, R. (1992). Evidence that dyslexia may represent the lower tail of a normal distribution of reading ability. *The New England Journal of Medicine*, *326*(3), 145–150. https://doi.org/10.1056

Shipstead, Z., Hicks, K. L., & Engle, R. W. (2012). Cogmed working memory training: Does the evidence support the claims? *Journal of Applied Research in Memory and Cognition*, *1*(3), 185–193. https://doi.org/10.1016/j.jarmac.2012.06.003

Swanson, J. M., Schuck, S., Porter, M. M., Carson, C., Hartman, C. A., Sergeant, J. A., … Wigal, T. (2012). Categorical and dimensional definitions and evaluations of symptoms of ADHD: History of the SNAP and the SWAN rating scales. *International Journal of Psychological Assessment*, *10*(1), 51–70. https://doi.org/10.1037/emo0000122.Do

Thorell, L. B. (2007). Do delay aversion and executive function deficits make distinct contributions to the functional impact of ADHD symptoms? A study of early academic skill deficits. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *48*(11), 1061–1070. https://doi.org/10.1111/j.1469-7610.2007.01777.x

Visser, S. N., Danielson, M. L., Bitsko, R. H., Holbrook, J. R., Kogan, M. D., Ghandour, R. M., … Blumberg, S. J. (2014). Trends in the parent-report of health care provider diagnosed and medicated ADHD: United States, 2003-2011. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*(1), 34–46. https://doi.org/10.1002/dev.21214.Developmental

Wåhlstedt, C. (2009). Neuropsychological deficits in relation to symptoms of adhd: Independent contributions and interactions. *Child Neuropsychology*, *15*(3), 262–279. https://doi.org/10.1080/09297040802524198

Warner-Rogers, J., Taylor, A., Taylor, E., & Sandberg, S. (2000). Inattentive behavior in childhood: *Journal of Learning Disabilities*, *33*(4), 520–536.

Weiss, M., Worling, D., & Wasdell, M. (2003). A chart review study of the Inattentive and Combined Types of ADHD. *Journal of Attention Disorders*, *7*(1), 1–9. https://doi.org/10.1177/108705470300700101

Willcutt, E. G., & Pennington, B. F. (2000). Psychiatric comorbidity in children and adolescents with reading disability. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *41*(8), 1039–1048. https://doi.org/10.1017/S0021963099006368

Woodcock, R. W., McGrew, K. S., & Mather, N. (2003). *Woodcock-Johnson III Tests of Achievement*. *Riverside Publishing*.

Yeniad, N., Malda, M., Mesman, J., Van Ijzendoorn, M. H., & Pieper, S. (2013). Shifting ability predicts math and reading performance in children: A meta-analytical study. *Learning and Individual Differences*, *23*(1), 1–9. https://doi.org/10.1016/j.lindif.2012.10.004

CHAPTER 3

Exploring N-Back Cognitive Training for Children with ADHD

Attention Deficit Hyperactivity Disorder (ADHD) is a developmental disorder characterized by inattention, hyperactivity, and impulsive behavior. It is common; the National Survey of Children’s Health found that in 2011, 11% of US children ages 4-17 (i.e., 6.4 million) had ever been diagnosed with ADHD and 9% of children had a current diagnosis of ADHD (Visser et al., 2014) though prevalence rates vary across studies and hover around 6% in international samples (Moffitt et al., 2015; Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014). ADHD symptoms typically arise early in life (median age of diagnosis is 6 years; Visser et al., 2014), generally continue through adolescence, and persist into adulthood for 30-60% of individuals diagnosed (Barkley, 1997; Barkley, Fischer, Smallish, & Fletcher, 2002; Faraone, Biederman, & Mick, 2005; Matte et al., 2015; Moffit et al., 2015). Approximately 80% of children with ADHD have academic performance problems and have a higher incidence of grade retention and dropping out of school compared to children without ADHD (DuPaul & Stoner, 2014). As a result, ADHD often contributes to academic, social, and employment difficulties throughout the lifespan (Barkley et al., 2002). Given the prevalence of ADHD, the chances are high that classrooms with 20 or more students include at least one individual with ADHD (Abikoff et al., 2002). Because children with ADHD can be disruptive, learning of all students in the classroom can be affected (August et al., 1996). Thus there is a strong, practical need for the development of effective interventions to mitigate the symptoms and consequences of ADHD.

Though there are many facets to ADHD, the present study focuses primarily on working memory, inhibition, and the ADHD behaviors associated with those executive functions. Children with ADHD show impairments on a variety of working memory-related and executive control tasks. On average, children with ADHD perform worse than typically developing children on standard working memory tasks (Karatekin & Asarnow, 1998; McInnes, Humphries, Hogg-Johnson, & Tannock, 2003; Sonuga-Barke, Dalen, Daley, & Remington, 2002; Westerberg, Hirvikoski, Forssberg, & Klingberg, 2004), and a number of studies have documented impairments among children with ADHD in executive function tasks, including the Wisconsin Card Sorting Test (Pineda et al., 1998; Reeve & Schandler, 2001), verbal fluency tasks (Pineda et al., 1998), the Stroop task (Reeve & Schandler, 2001), task-switching (Cepeda, Cepeda, & Kramer, 2000; White & Shah, 2006), and the Tower of London task (Cornoldi, Barbieri, Gaiani, & Zocchi, 1999). This is likely due to lower working memory capacity and reduced cognitive control in individuals with ADHD. As inhibitory and working memory skills are implicated in scholastic and non-scholastic achievement (Friso-Van Den Bos, Van Der Ven, Kroesbergen, & Van Luit, 2013; Mcvay & Kane, 2012; St Clair-Thompson & Gathercole, 2006), interventions specifically targeting these mechanisms could be of great benefit for children with ADHD.

Interventions for ADHD

There are various approaches for ameliorating the challenges associated with ADHD; the most common method is stimulant medication. There are also non-pharmacological strategies such as behavioral interventions and cognitive training; some of these methods are often used in combination with stimulant medication.

Medication. Although medication can be of great help, they are ineffective for up to 30% of individuals with ADHD (Banaschewski, Roessner, Dittmann, Santosh, & Rothenberger, 2004). Furthermore, though ADHD medications are often seemingly effective in laboratory contexts, they seem to have less impact on everyday functional outcomes (Pelham et al., 2017). In addition, they are often associated with side effects such as reduced appetite and sleep disturbances

(Banaschewski et al., 2004). For these and other reasons, approximately 20% of individuals with ADHD cease stimulant use within the first year of taking them (Toomey, Sox, Rusinak, & Finkelstein, 2012). It is not our aim to report a thorough overview on this topic, but interested readers may refer to Rubia et al. (2014) for a meta-analysis.

Behavioral Therapy. The most widely used non-pharmacological interventions for children with ADHD is behavioral management therapy (Evans, Owens, & Bunford, 2013; Wolraich et al., 2011). In these interventions, teachers (behavioral classroom management), or parents (behavioral parent therapy) are taught to reinforce children when they perform a desired behavior and to ignore undesired behaviors. This approach helps children to learn self-regulation skills, with typical outcomes including improved compliance to parent and teacher directions, as well as decreased disruptive behavior in the classroom. While behavioral therapies are generally considered the most effective non-pharmacological approaches for addressing ADHD symptomatology (Evans et al., 2013; Fabiano et al., 2009), many issues prevent these interventions from being available and effective for all children. Behavioral therapies can incur significant financial and time investments. Furthermore, new meta-analytic work suggests that although behavioral therapies may be successful in individual studies, a variety of factors related to both the design of the intervention and individual difference factors across participants may limit their effectiveness (Sonuga-Barke et al., 2013).

Cognitive Training. Another approach to treat ADHD is the use of “cognitive training” programs aimed at the core executive function deficits associated with ADHD. This approach is attractive in that, if effective, it may be lower in cost in terms of time, money, and potential side effects. Indeed, a recent meta-analysis of cognitive training (Cortese et al., 2015) and non-pharmacological interventions for ADHD more broadly (Sonuga-Barke et al., 2013), cognitive training was identified as an area that requires further exploration. As such, our study contributes to the growing literature on cognitive training interventions for individuals with ADHD. Currently, the most widespread and highly researched cognitive intervention for ADHD is Cogmed working memory training (CWMT), an online working memory training program that targets primarily the storage aspects of both verbal and visuospatial working memory. It is marketed to schools and clinicians as a tool for improving cognitive abilities, such as attention and reasoning (Roberts et al., 2016). Some studies of CWMT in children with ADHD have shown improvements in ADHD-related symptoms as a function of training (Beck, Hanson, Puffenberger, Benninger, & Benninger, 2010; Klingberg et al., 2005; Klingberg, Forssberg, & Westerberg, 2002; Mezzacappa & Buckner, 2010), and a recent study by Bigorra, Garolera, Guijarro, and Hervas (2016) demonstrated reductions in inhibitory control, as measured by CPT errors of commission. However, others have failed to replicate those findings, leading to conflicting reviews and meta-analyses (Chacko et al., 2013; van der Donk, Hiemstra-Beernink, Tjeenk-Kalff, van der Leij, & Lindauer, 2015; Shipstead, Hicks, & Engle, 2012). Additional challenges regarding CWMT include lengthy sessions (approximately 40 minutes per day over the course of 5 weeks), the necessity of a coach, and the significant cost (Chacko et al., 2014).

Other cognitive training work has attempted to target inhibition directly. Shavlev, Tsal, & Mevorach (2002), found improvements in attention and academic outcomes following an attentional control training program. Conversely, a recent large, randomized controlled trial of inhibitory control training found no evidence for training and transfer effects (Enge et al., 2014). Although some of the evidence is mixed, it may remain possible to train inhibition, especially if it occurs in combination with training working memory, as there seems to be considerable overlap between the domains of working memory and inhibitory control (Hsu, Jaeggi, & Novick, 2017).

Specifically, we have demonstrated transfer to inhibition via an inhibition and working memory-demanding executive functioning task, the n-back task, in young adults (Hsu, Buschkuehl, Jonides, & Jaeggi, 2013) and typically developing children (Jaeggi, Buschkuehl, Jonides, & Shah, 2011). The n-back task requires participants to respond to a series of stimuli by judging whether each stimulus is the same as the one presented n-items previously. The n-back task requires both active maintenance and updating of items in working memory as well as deleting items that are further back in a sequence. It also requires inhibiting responses to near target items, or lures. In Jaeggi and colleagues (2011), inhibition was measured by the Conners' Continuous Performance Task (CPT), which requires children to respond to all alphabetic letters appearing intermittently on a but withhold responses to the letter "X." On average, children in the n-back training group exhibited fewer errors of commission compared to peers in a control condition. These results suggest that n-back training may be especially beneficial for children with ADHD, given that they are thought to suffer from underlying issues of inhibitory control. Furthermore, the CPT is often used as a diagnostic measure for ADHD in neuropsychology testing (e.g., Corkum & Siegel, 1993).

Based on the previous work in this domain, the goal of the present study was to examine whether training on the n-back task would improve the response inhibition skills of children with ADHD. Children with ADHD trained on a visuospatial version of the n-back task that was previously used with typically developing children (Jaeggi, Buschkuehl, Jonides, Shah, et al., 2011). The participants' performance was compared with that of an active control group that trained on vocabulary and general knowledge. Based on our prior work finding improvements on measures of response inhibition in typically-developing children and young adults, our primary hypothesis was that children with ADHD would also show improvements in response inhibition as measured by the CPT. Furthermore, because inhibitory control is purported to be a mechanism underlying self-regulation and cognitive/achievement deficits in children with ADHD, we expected training on the n-back task may also lead to decreased ADHD symptoms (as measured by parent report) and improved academic ability (as measured by performance on math and reading measures from the Woodcock Johnson III; Woodcock, McGrew, & Mather, 2003). Such a result would inform developing theories of cognitive training, offer support for theories implicating low inhibitory control as a contributor to ADHD, and provide preliminary evidence of the efficacy of n-back training as a useful intervention for children with ADHD. We also assessed general knowledge at posttest and delayed posttest as a control measure. For this task, which was largely identical to the training performed by the control group, we predicted that the control group would outperform the training group at delayed posttest.

Previous work has demonstrated improvements in working memory and fluid reasoning in typically-developing young adults following n-back training (Au, Sheehan, et al., 2015; Au, Buschkuehl, Duncan, & Jaeggi, 2016). And furthermore, typically-developing children who showed improvement on the n-back task also demonstrated improvements on measures of fluid reasoning (Jaeggi, Buschkuehl, Jonides, Shah, et al., 2011). We predicted that the training group in our study might outperform the control group on measures of working memory and fluid reasoning, however, fluid reasoning was considered exploratory, as there has been only limited evidence of fluid reasoning improvements in samples of children with learning or attention disorders. Based on our previous work, we also tested whether performance may be related to quality of training on the n-back task.

Children were assessed before training, immediately after training, and again after a three-month delay. The purpose of the immediate posttest was to test for immediate changes as a result of training, and the purpose of the delayed posttest was twofold: to see whether any immediate changes could be sustained over time and to see whether any changes would manifest after a delay even if they were not measurable at immediate posttest. If improved inhibition leads to improved self-regulation, such changes may not be detectable in parent reports of ADHD symptomology without some period of time post-training. Likewise, if improved inhibition is beneficial for learning, and such changes may not have time to be reflected in achievement till students can use their enhanced inhibitory control skills in learning situations. Indeed, other cognitive interventions that impact academic achievement often do so only after delay (e.g., Klauer & Phye, 2008).

Finally, there is evidence that in cognitive training not all participants benefit equally from training (Hussey & Novick, 2012; Katz, Jones, Shah, Buschkuehl, & Jaeggi, 2016; Jaeggi et al., 2011). Those who perform well on the training task tend to benefit more from the training, demonstrating greater improvements on untrained tasks such as reasoning and reading comprehension (Hussey & Novick, 2012; Jaeggi, et al., 2011). It is possible that others lack interest during training, or that they experience difficulty coping with the frustrations of the task as it became more challenging. The latter explanation is particularly likely in the case of children with ADHD, who tend to struggle with overcoming frustration (Seymour, Macatee, & Chronis-Tuscano, 2016). Accordingly, we predicted that the children with ADHD in our sample would vary in terms of training task performance, and that the training task performance would be related to performance on transfer tasks and parent report measures.

Method

Participants

This study was approved by the appropriate ethics committee and performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. One hundred and eight children with ADHD from the communities around the University of

Michigan were recruited to participate in the study via fliers and advertisements posted in primary care offices, schools and local newspapers. Parents were told that children would participate in a training protocol that might improve attention and problem solving skills. The only compensation for participants were small prizes (e.g., tickers, pencils, or small stuffed animals). Informed consent was obtained from all individual participants included in the study. Most children were from upper middle-class backgrounds (see Table 3.1). Seven were excluded due to comorbid diagnoses in addition to ADHD (e.g., autism). For data analyses, we included only participants who completed at least 15 out of 20 training sessions and who trained for at least four weeks, but not longer than six weeks, and who had no major training or posttest scheduling irregularities (such as training three times per day instead of once a day). Based on those criteria, we excluded twenty-one children for failure to comply with the training schedule. Our final sample consisted of 80 children (*mean age*: 10.14 years; *SD*: 2.02; *range*: 7-14; 25 *girls*). All participants met diagnostic criteria on the The Conners' Parent Questionnaire – Revised: Long Form (CPRS–R:L; Conners, Sitarenios, Parker, & Epstein, 1998; Conners, 2001) or the The Child Behavior Checklist (CBCL; Achenbach, 1991; Chang, Wang, & Tsai, 2016). Additionally, all participants had been diagnosed with ADHD by a clinician (i.e., pediatrician, psychologist or psychiatrist), according to Diagnostic and Statistical Manual of Mental Disorders (*DSM-IV Diagnostic and Statistical Manual of Mental Disorder*, 1994) criteria. Although the ADHD diagnoses made by clinicians were not standardized across participants, we chose this present approach as it is representative for how ADHD is typically diagnosed in the community, and furthermore, our main goal was to test the efficacy of our intervention in an ecologically valid context. Participants could be no younger than seven, as the control task required participants to read at a somewhat fluent level. Participants could also be no older than 14, as the task design and background stories of the intervention were created with younger children in mind, and might not have been appropriately engaging for older adolescents.

As they were recruited, participants in the two groups were continuously matched on measures of fluid reasoning (TONI and SPM), age, gender and ADHD symptom severity (as measured by parent rated CPRS–R:L Comprehensive Behavior Rating Scales) by a researcher who was neither involved in testing nor in training of the participants. Based on this matched pairing, participants were randomly assigned to one of two conditions: n-back training (n=41) or an active knowledge training control condition (n=39). Of these participants, 19 in the training group and 15 in the control group were actively taking medication for ADHD. See Table 3.1 for full demographic information.

Table 3.1
Participant Demographic Information

	Training Group Mean *(SD)*	Control Group Mean *(SD)*	*p*-value	*BF*
N	41	39		
Age	10.22 *(2.04)*	10.05 *(2.03)*	0.71	0.25
Grade	4.78 *(2.13)*	4.72 *(2.08)*	0.90	0.23
ADHD Severity	23.15 (*7.34*)	23.68 (*7.03*)	0.74	0.25
Num. Girls	13	12	0.93	0.25
Num. Medicated	20	18	0.93	0.29
Mother’s Education	16.57 *(2.5)*	16.44 *(2.30)*	0.39	0.25
Family income	$25,000–99,000	$25,00–99,000	0.69	0.003

Note: ADHD Severity as measured by parent report on the CPRS-R:L ADHD index at pretest, mother’s education is measured in years, and income mode is presented, as income was measured in bins. The *p*-values and Bayes factors are from t-test from continuous variables and from chi-squared tests for non-continuous variables. Bayes factors over 1 are considered evidence in favor of the alternative hypothesis.

Table 3.2
Demographic Information for included and excluded participants

	Included Mean *(SD)*	Excluded Mean *(SD)*	*p*-value	*BF*
N	80	21		
Age	9.9 (0.43)	10.13 (0.22)	0.63	0.24
Grade	4.62 (0.45)	4.75 (0.23)	0.79	0.23
ADHD Severity	25.95 (1.61)	23.41 (0.79)	0.16	0.02
Num. Girls	25	4	0.14	0.29
Num. Medicated	38	14	0.26	1.19
Mother's Ed	16.63 (0.54)	16.51 (0.28)	0.84	0.01
Family income	$25,000–99,000	$25,000–99,000	0.89	0.26

Note: ADHD Severity as measured by parent report on the CPRS-R:L ADHD index at pretest, mother's education is measured in years, and income mode is presented, as income was measured in bins. The *p*-values and Bayes factors are from t-test from continuous variables and from chi-squared tests for non-continuous variables. Bayes factors over 1 are considered evidence in favor of the alternative hypothesis.

Procedure

Participants came to the lab for two 60-minute sessions to complete pretest measures. Pretest measures included tasks that were structurally similar to the training tasks (termed "near transfer"), tasks that were dissimilar to the training tasks ("far transfer"), and parent report measures. Participants were required to train at home once per day for 20 sessions with parent supervision, and in addition, children came to train in the lab, a library, or another public place once a week for a researcher-supervised training session (16 sessions at home, 4 sessions supervised, over the course of about 5 weeks). The children returned for a posttest session immediately following training completion, and they returned again for a second, delayed posttest to complete the same measures three months later to discern whether any differences between groups persisted over time. All pretest, posttest, and delayed posttest descriptive statistics along with re-test reliability estimates and effect sizes are provided in the appendix I.

Measures

N-Back Training. Participants in the experimental condition trained on a game-like computerized cognitive training task similar to that used in previous studies with typically developing children (Jaeggi, Buschkuehl, Jonides, Shah, et al., 2011). This spatial n-back task presented participants with images at one of six locations on the screen at a rate of three seconds each, each image presented for 500 ms followed by a 2,500 ms interstimulus interval. The participants' task was to decide whether a stimulus appeared at the same location as the one presented *n* items back in the sequence. Participants pressed the 'A' key each time the current image was in the same location as the one presented *n* items previously (targets) and the 'L' key if the image did not match (non-targets). There were five randomly positioned targets per block of trials, and each block included 15 + *n* trials. Each training session consisted of 10 rounds lasting approximately one minute each. Participants were provided with performance feedback at the end of each round as well as at the end of the training session. A complete training session lasted approximately 15 minutes.

The levels in the game corresponded to the *n* back that the participant had to remember. The *n* was adaptive, such that successfully completing a round at a particular level (three or fewer errors) resulted in the next round being more difficult by increasing the level of *n*, whereas poor performance (four or more errors) resulted in “losing a life.” At the end of each round, points were calculated and awarded in the form of virtual gold coins. At higher levels that were more challenging, more points were awarded per correct response and more points could be earned per round. If three lives were lost on a same level, the player would be moved down one level and receive three more lives. Moving down a level was not intended as a penalty, but rather as a means to keep the difficulty of the game within the participants’ level of maximum ability.

Control Training. Participants in the active control training group completed a general knowledge and trivia program as used before (Jaeggi, Buschkuehl, Jonides, Shah, et al., 2011), in which they answered questions about vocabulary, history, and general-knowledge facts. Time on task and reinforcers were similar as time for the n-back training group. Questions such as “What is Orion’s Belt?” were presented and participants selected from four answer alternatives shown below the question. Participants were provided with feedback on their performance, and questions which were answered incorrectly were repeated in the next session. This game also had levels and was adaptive, but only minimally implicated working memory or controlled attention.

There were four different themes in both the n-back and the control training. The themes were implemented in order to make the training task more interesting for children. After five training sessions, the theme would automatically switch to the next one. The general training features (e.g., levels, bonuses, scores) would stay the same regardless of the presented theme. While playing the games at home, the child would be earning points and virtual gold coins, which he or she would later be able to trade in for trivial prizes (stickers, pencils, stuffed animals, etc.) after the supervised training sessions. Participants received no other compensation.

Near Transfer Tasks. The participants completed an untrained (non-spatial/identity) version of the n-back task as previously used (Katz, Jaeggi, Buschkuehl, Stegman, & Shah, 2014), in which they were presented with a series of colored objects (e.g. a penguin, a flower, a lemon) in the center of the screen, and they had to indicate whether or not the current stimulus was the same as the one n positions back in the sequence. Unlike the training task, which was adaptive, the n-back level was fixed at 2-back, and children completed only three rounds (20+n trials each). The fixed level of n-back was chosen based on our previous work with typically developing children (Jaeggi et al., 2011), showing that this task at that level and using those stimuli is adequate in terms of difficulty, in that we were expecting enough variability allowing us to assess transfer. The fixed level also allowed us to assess participants' attention and impulsivity (noticing and rejecting lure trials) in addition to working memory. The dependent variable was the proportion of hits minus the proportion of false alarms. This task was administered at pretest, posttest, and at delayed posttest. Participants also completed a multiple-choice quiz similar to the control training task. This was included as a near transfer task for the control group and a control task for the n-back training group as we did not predict improvements in general knowledge as a function of cognitive training. This quiz was administered at posttest and at delayed posttest only.

Cognitive Far Transfer Tasks. These measures were administered at pretest, posttest, and delayed posttest. We used the CPT to assess sustained attention and inhibitory control by having participants respond as quickly as possible to stimuli (letters; go trials), but to withhold responses for a small percentage of trials (i.e., upon presentation of the letter “X”; no-go trials). The letters were presented in the center of the screen (white on black background) for a duration of 250 ms. Our task was modeled after Conners et al., (2003), consisting of 18 blocks with 20 trials each (360 total trials). Each block differed in the duration of the interstimulus interval, which was 1,000, 2,000, or 4,000 ms long. The order of the blocks was randomized. The ratio of go- vs. no-go trials was 9:1. Our dependent measure was false alarm rates. Split-half reliability for the CPT has been reported as 0.83 (range 0.66 to 0.95; Conners et al., 2000; 1994).

All participants completed two verbal working memory measures that were not n-back tasks. For analyses, a composite score of working memory was created using standardized z-scores averaged from both tasks, i.e. Digit Span (forward and backward) and Following Directions. The digit span required participants to read lists of digits and repeat them either in order (forward digit span) or in the reverse order of presentation (backward digit span; Wechsler, 2003). List lengths varied from two to nine (two trials per list length), and the task was ended if participants failed at both trials of a particular list length. The dependent variable was the number of correctly recalled sequences. Parallel-test versions (counterbalanced across participants) were used for pre- and posttest, however, for the delayed posttest, the version used at pretest was administered. In the following directions task (Gathercole, Durling, Evans, Jeffcook, & Stone, 2008), participants were seated in front of an array of familiar objects (boxes, folders, pencils, rulers, erasers) in three different colors (blue, yellow, and red). Participants were asked to execute a spoken instruction such as “Pick up the blue pencil and put it in the yellow box.” The task instructions became increasingly complex (i.e., containing more actions) throughout the measure, up to a level when the participant made three consecutive errors within one level of complexity. The number of actions ranged from one to seven (levels 1–7), and each level contained six trials. The dependent variable was calculated as the sum of the number of actions in sequence that the child could accurately complete all trials of, plus 0.25 for each correct trial at the next span level. For example, if a child successfully completed six trials with three actions (this counts three towards the dependent variable), completes one correct trial with four actions (this counts 0.25 towards the dependent variable), then fails the subsequent trials with four actions, their score would be a span of 3.25 (Holmes, Gathercole, & Dunning, 2009; see also Ramani, Jaeggi, Daubert, & Buschkuehl, 2017). Parallel-test versions (counterbalanced across participants) were used for pre- and posttest, and for the delayed posttest, the version used at pretest was administered.

Far Transfer to ADHD Symptoms. Three standardized parent questionnaires were administered at pretest and at the delayed posttest three months after the training had ended, providing insight into whether there were any observable behavioral differences resulting from cognitive training. Here we focus on specific sub-scales measuring ADHD symptoms related to executive functioning, but for completeness, the descriptive data for all scales are provided in Appendix I, Table 3.

The CBCL assesses behavioral problems in children. Cronbach's alpha for the narrow scales (syndrome and DSM-oriented) is reported as 0.83, and for the broad scales (internalizing, externalizing, and total problems), it is 0.94 (Bullard, Griss, Greene, & Gekker, 2013). The Behavior Rating Inventory of Executive Function (BRIEF**;** Gioia, Isquith, Guy, & Kenworthy, 2000) measures executive functioning in children. Cronbach's alpha for the scales range from 0.80–0.98 (Gioia et al., 2000). The CPRS–R:L provides seven scales: oppositional, cognitive problems/inattention, hyperactivity-impulsivity, anxious-shy, perfectionism, social, and psychosomatic problems. Cronbach's alpha for the scales range from 0.75–0.95 (Conners et al., 1998).

For the purpose of the present paper, specific scales were selected for analyses based on our hypotheses. Parent report of executive functioning was measured using the BRIEF Executive Functioning sub-scale. As we were interested in inattention and hyperactivity, we used composite z-scores from the following scales: attention problems and ADHD problems from the CBCL and the inattention and hyperactivity scales from the CPRS–R:L. This approach was taken to minimize familywise error inflation, reducing the overall number of comparisons. However, for completeness, the descriptive results of all scales are reported in Appendix I, Table 3.

School-Related Far Transfer Tasks. Three school-related tasks were administered. For analyses, a composite score for academic ability was created using z-scores from the Woodcock Johnson III Passage Comprehension, Math Applied Problem Solving, and Reading Fluency (Woodcock et al., 2003). Individual test reliabities using a split half method are reported as 0.80 or higher (Grenwelge, 2009). For all school-related tasks, parallel-test versions (counterbalanced across participants) were administered for pre- and post-test, and for the delayed posttest, the version used at pretest was administered. The Passage Comprehension subtest of the Woodcock Johnson III was used to measure participants' reading comprehension. Participants read progressively more challenging passages and answered questions about them. The cut-off for this task was six sequential incorrect responses within a set, and the dependent variable was the total number of correct responses. The Math Applied Problem Solving subset of the Woodcock Johnson III was used to measure participants' broad math skills. Participants solved math word problems. The cut-off for this task was six sequential incorrect responses in a set, and the dependent variable was the total number of correct responses. The Reading Fluency subtest of the Woodcock Johnson III was used to measure participants' automaticity in reading simple sentences. Participants were given three minutes to read simple sentences and judge if those sentences were true or false. The dependent variable was the number of correctly answered questions.

Far Transfer to Matrix Reasoning. Participants were presented with incomplete, abstract patterns to be completed by selecting the missing part that logically completes the pattern or series. We used two standardized versions, the Ravens Standard Progressive Matrices (SPM; Raven, 2000) and the Test of Nonverbal Intelligence (TONI; Brown, 2003) The odd-even split-half corrected coefficient of reliability for SPM is 0.96 (Raven, 2000), and Cronbach's alpha for TONI is reported in the 0.80 and 0.90 range (Brown, 2003). The cut off for the Ravens was 10 minutes, and the cut off for the TONI was three incorrect answers out of a sequence of five items. The dependent measure was the amount of correctly solved problems. We created a composite score for matrix reasoning using standardized z-scores averaging the scores of both measures. These tasks were administered at pretest, posttest, and at delayed posttest. Parallel-test versions (counterbalanced across participants) were administered for pre- and posttest, and for the delayed posttest, the version used at pretest was administered.

Results

Primary Analyses

Data were analyzed using IBM SPSS Statistics Version 22 and JASP Version 0.8.5.1. Descriptive data for the near and far transfer tasks are provided in Appendix I, Tables 1, 2, and 3. Appendix I Tables 4 and 5 provide correlations between outcome measures at pretest, training gain, and gains on outcome measures. Note that there were no significant differences between groups on any of the variables of interest at pretest (all *p*s > .20). We interpret significance at the $p < 0.05$ level, but as this is an exploratory study, we provide the reader with rich information with which to assess our findings. This includes uncorrected *p*-values and *p*-values corrected for multiple comparisons using the Hochberg-Benjamini method (Hochberg & Benjamini, 1990), and in addition, we conducted Baysean analyses using default priors in JASP, which allow us to report Bayes Factors that quantify evidence for and against the null hypothesis (Wagenmakers et al., 2017).

First, data were analyzed to test whether any significant group differences existed at pretest. Both groups completed an equivalent number of training sessions (experimental group: *mean*: 19.15; *SD*: 2.69; control group: *mean*: 19.62, *SD*: 1.71; $t(78) = -0.93$, $p = 0.36$, $d = 0.21$). On average, children with ADHD improved by approximately half an n-back level, which is slightly below the improvement that has been observed in typically developing children (Jaeggi et al., 2011). Then, our general approach to testing for differences between the training and the control group resulting from cognitive training was to conduct two-group analyses of covariance. We analyzed the posttest performance using pretest as a covariate to test for immediate training efficacy. All analyses met the assumptions for ANCOVA with the exception of school-related skills at posttest, which violated the assumption of homogeneity of slopes. The analysis for this particular measure was therefore performed as an Analysis of Variance without a covariate. These posttest results are presented in Table 3.3. Then we analyzed the delayed posttest with the pretest as a covariate to test for sustained changes. All these analyses met the assumptions for ANCOVA, and the results are presented in Table 3.4.

In short, at post-test, we observed strong evidence of group differences in the non-trained n-back task ($F(1,77) = 11.41$, $p = 0.001$, $\eta^2_p = 0.13$, $BF = 29.50$), as well as well as substantial evidence for group differences in the measure of inhibitory control (CPT; $F(1, 77) = 6.48$, $p = 0.01$, $\eta^2_p = 0.08$, $BF = 3.73$). At delayed post-test, the group differences remained, however, the effects were less pronounced than at post-test, and furthermore, they did not survive corrections for multiple comparisons (non-trained n-back: $F(1, 54) = 4.56$, $p = 0.04$, $\eta^2_p = 0.08$, $BF = 1.74$; CPT: ($F(1, 54) = 4.34$, $p = 0.04$, $\eta^2_p = 0.07$, $BF = 1.55$), see figure 3.1. We also observed anecdotal evidence of reduced ADHD symptoms as reported by the parents ($F(1, 43) = 3.38$, $p = 0.07$, $\eta^2_p = 0.07$, $BF = 1.11$; see figure 3.2). Descriptive statistics by group for pretest, posttest, and delayed posttest are displayed in Table 3.5.

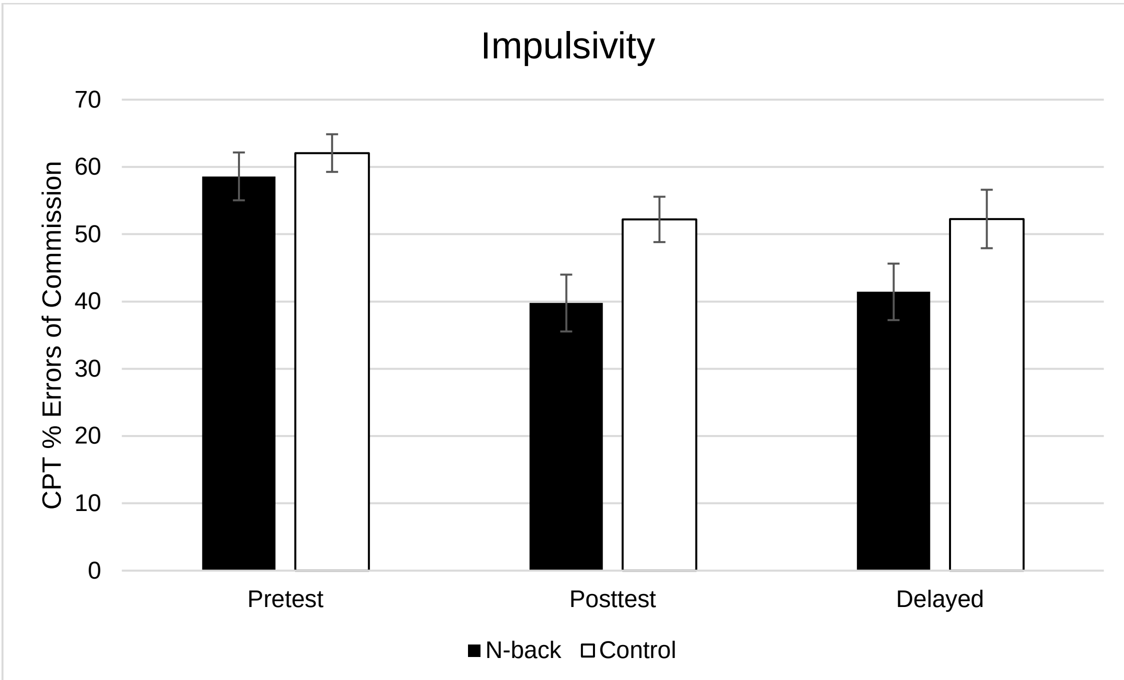


Figure 3.1: Performance on impulsivity task (CPT errors of commission) by training group. Lower scores indicate better performance. Error bars represent standard errors.

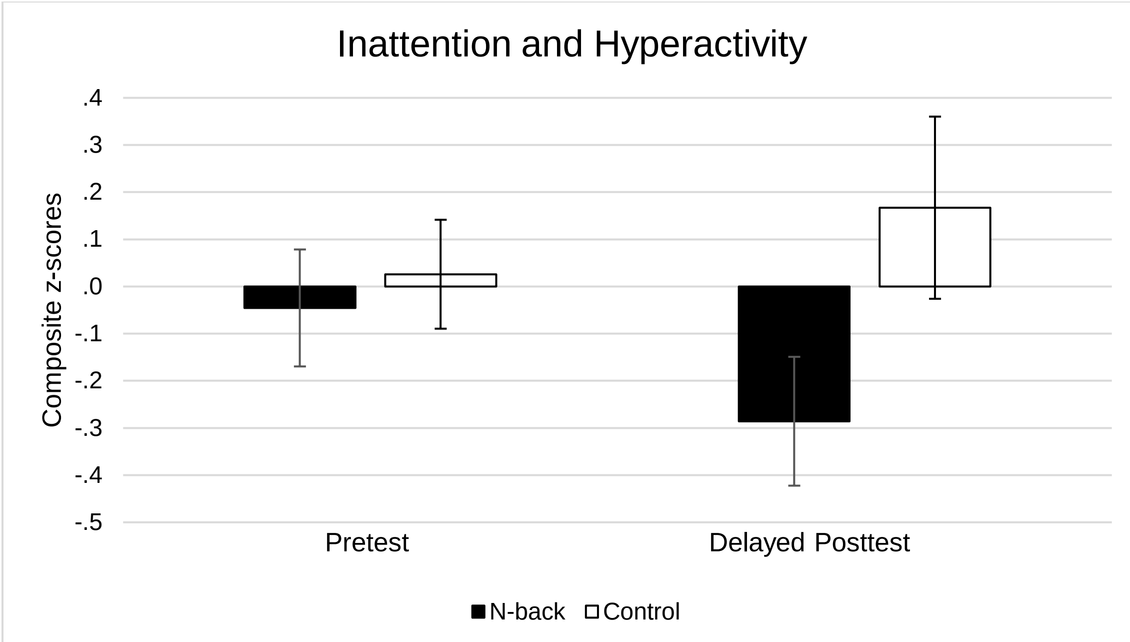


Figure 3.2: Parent rating of inattention and hyperactivity by training group. Note that better performance is represented by negative numbers (i.e. fewer symptoms). Error bars represent standard errors.

Table 3.3

ANCOVA Posttest Results

Outcome Measure	*F* (1, 77)	Non-adjusted *p*-value	Adjusted *p*-value	η^2_p	*BF*
Object n-back	11.41	.001***	0.01**	0.13	29.50
Trivia	.10	.76	0.76	0.00	0.25
CPT	6.48	.01**	0.03*	0.08	3.73
Working Memory	1.99	.16	0.26	0.03	0.61
School-related tasks	1.54	.22	0.26	0.02	0.32
Matrix Reasoning	1.79	.19	0.26	0.02	0.53

Note: Adjusted and unadjusted p-values are reported. Adjusted p-values were calculated using the Hochberg-Benjamini method. Significance levels are indicated as: 0.001 = ***, 0.01 = **, 0.05 = * Bayes factors over 1 are considered evidence in favor of the alternative hypothesis. School-related tasks did not control for pretest performance, as assumptions for ANCOVA were not met in this case.

Table 3.4
ANCOVA Delayed Posttest Results

Outcome Measure	*F* (1, 54)	Non-adjusted *p*-value	Adjusted *p*-value	η^2_p	*BF*
Object n-back	4.56	.04*	.11	0.08	1.74
Trivia	0.54	.47	.54	0.01	0.33
CPT	4.34	.04*	.11	0.07	1.55
Working Memory	5.48	.02*	.11	0.09	2.32
Inattention and Hyperactivity	3.38	.07	.14	0.07	1.11
Executive Functioning	1.99	.17	.27	0.05	0.68
School-related tasks	.93	.34	.45	0.02	0.44
Matrix reasoning	0.02	.87	.87	0.00	0.26

Note: Adjusted and unadjusted p-values are reported. Adjusted p-values were calculated using the Hochberg-Benjamini method. Significance levels are indicated as: 0.001 = ***, 0.01 = **, 0.05 = *. Bayes factors over 1 are considered evidence in favor of the alternative hypothesis.

Table 3.5
Descriptive statistics by group for the outcome variables at pretest, posttest, and delayed posttest

Outcome Measure	Active Control Group Pretest Mean (SD)	Posttest Mean *(SD)*	Delayed Posttest Mean *(SD)*	N-Back Group Pretest Mean *(SD)*	Posttest Mean *(SD)*	Delayed Posttest Mean *(SD)*
Object n-back	0.34 *(0.22)*	0.39 *(0.23)*	0.42 *(0.28)*	0.40 *(0.24)*	0.59 (0.27)	0.54 *(0.21)*
Trivia	n/a	9.12 *(3.72)*	9.53 *(3.49)*	n/a	8.86 *(3.57)*	8.83 *(3.71)*
CPT	62.06 *(17.05)*	52.20 *(21.15)*	52.27 *(22.15)*	58.60 *(22.77)*	39.77 *(27.36)*	41.44 *(23.36)*
Working Memory	-0.03 *(0.91)*	-0.12 *(0.89)*	-0.17 *(0.92)*	0.08 *(0.82)*	0.14 *(0.84)*	0.20 *(0.66)*
Inattention and Hyperactivity	0.03 *(0.71)*	n/a	0.17 *(0.89)*	-0.05 *(0.79)*	n/a	-0.29 *(0.68)*
Executive Functioning	67.50 *(9.05)*	n/a	66.14 *(9.84)*	65.48 *(9.66)*	n/a	59.73 *(10.93)*
School-related tasks	-0.07 *(1.04)*	-0.16 *(1.05)*	-0.02 *(1.06)*	0.03 *(0.83)*	0.10 *(0.71)*	0.07 *(0.66)*
Matrix reasoning	-0.02 *(0.95)*	-0.12 *(0.96)*	0.07 *(0.94)*	0.01 *(0.90)*	0.09 *(0.92)*	-0.02 *(0.94)*

Note: n/a indicates that values are not applicable for tests that were not administered at those time points.

Finally, multiple regression analyses were conducted to test whether the amount of training improvement in the training group predicted performance on untrained measures (see Table 3.6). Training improvement was measured as the average score on the last two training sessions minus the average score on the first two training sessions. This approach was guided by our hypothesis that cognitive training is most effective when participants are actively engaged and put effort into doing their best. Assumptions for multiple regressions were tested and met. The analyses suggested that training performance was predictive for transfer in several measures, specifically, in CPT at posttest (b = -6.93, p = 0.03, BF = 1.34), parent-reported ADHD symptoms of inattention and hyperactivity (b = -0.26, p = 0.02, BF = 2.58), posttest school-related tasks (b = 0.14, p = 0.04, BF = 0.26), matrix reasoning at posttest (b = 0.21, p = 0.05, BF = 0.93), and matrix reasoning on delayed posttest (b = 0.36, p = 0.01, BF = 3.90).

Table 3.6
Regression analyses for the n-back group

	beta	*SD*	*t*	*p*-value	*BF*
CPT Errors of Commission Posttest					
Pretest	.96	.12	8.17	.00***	5.05×10^{6}
Training gain	-6.93	3.15	-2.20	.03*	1.34
CPT Errors of Commission Delayed Posttest					
Pretest	.80	.16	4.87	.00***	352.39
Training Gain	-7.17	3.84	-1.87	.07	1.09
Working Memory Posttest					
Pretest	.77	.13	5.88	.00***	27,915.89
Training gain	.00	.13	.02	.99	0.20
Working Memory Delayed Posttest					
Pretest	.40	.16	2.48	.02*	5.22
Training Gain	.06	.14	.43	.67	0.44
Inattention & Hyperactivity Delayed Posttest					
Pretest	.72	.12	6.00	.00***	2,134.52
Training gain	-.26	.11	-2.49	.02*	2.58
Executive Functioning Delayed Posttest					
Pretest	.92	.18	5.24	.00***	1,173.57
Training gain	.43	2.01	0.21	.83	0.23
School Tasks Posttest					
Pretest	0.72	.07	10.86	.00***	2.60×10^{9}
Training gain	.14	.06	2.16	.04*	0.95
School Tasks Delayed Posttest					
Pretest	.71	.10	7.34	.00***	152,512.54
Training gain	.08	.08	0.93	.36	0.26
Matrix Reasoning Post					
Pretest	.74	.09	7.8	.00***	2.46×10^{6}
Training gain	.21	.10	1.98	.05*	0.93
Matrix Reasoning Delayed Posttest					
Pretest	.07	0.13	5.14	.00***	625.09
Training gain	.36	0.14	2.64	.01**	3.90

Note: The effect of training gains on outcome measures controlling for pretest scores. Betas are unstandardized. Significance levels are indicated as: 0.001 = ***, 0.01 = **, 0.05 = *. Bayes factors over 1 are considered evidence in favor of the alternative hypothesis.

Exploratory Analyses

Motivation. To investigate the possibility that any effects were due to motivational differences between groups, all children were asked at the end of each training session to rate how much they enjoyed the training on a scale from 1–5 where 1 was “I really did *not* enjoy the game” and 5 was “I really enjoyed the game.” The average rating of the control group was 3.84 (SD = 0.89), and the average rating of the training group was 3.27 (SD = 0.84). The difference between the groups was significant (p = 0.004; d = 0.66), indicating that the control group enjoyed their task more than the training group. This suggests that any differences between groups cannot be attributed to the experimental group enjoying their task more than the control group.

Additionally, participants were asked to rate how much effort they put into the game in order to test for differences in engagement between group. Effort was rated on a 5-point scale where 1 was “very little” and 5 was “too much.” The average rating of the control group was 3.25 (SD = 1.13), and the average rating of the experimental group was also 3.23 (SD = 1.17). The difference between the groups was not significant (p = 0.92; d = 0.02), suggesting that neither group was more engaged than the other.

Medication. Although our limited sample size makes it difficult to compare children in the training group who were medicated (n=19) to children in the training group who were not medicated (n=15), the question of whether medication influences training efficacy is important enough to warrant an exploratory analysis. The training gain (the average score on the last two training sessions minus the average score on the first two sessions) was compared between medicated and un-medicated children. There was no significant training gain difference between groups (medicated: mean gain = .55, SD = .85; not medicated: mean gain = .84, SD = .77; p = .31,

d = .36), suggesting that the training program was equally beneficial for children who were and were not taking medication for their ADHD symptoms.

ADHD Severity. To explore the relationship between ADHD severity and training gain, a linear regression of ADHD symptoms (as measured by the Connors at pretest) on training gain was performed. ADHD severity did not significantly predict training gain (b = -.04, p = .08).

Discussion

Children who struggle with ADHD are hypothesized to have underlying executive functioning deficits, particularly in inhibitory control and working memory. In the present study, we tested the hypothesis that training children with ADHD in those two domains would lead to improvements on executive functioning skills that rely upon inhibition and working memory, and also to reductions in ADHD symptoms related to those executive functioning skills. Our results indicate that training inhibition, embedded in what is classically considered a working memory task, resulted in substantial improvements in a non-spatial variant of the n-back task, and in addition, we observed improved inhibitory control (as measured by the CPT), albeit with small effect sizes, and marginally reduced parent-reported symptoms of inattention and hyperactivity three months after training completion. However, this latter finding, which approached significance when uncorrected, failed to reach significance when adjusted for multiple comparisons. Nonetheless, we feel that this outcome is worth exploring in future studies with larger sample sizes. It remains possible that these symptoms may be reduced through cognitive training, which is relatively easy to implement compared to some other previously discussed interventions. Though these data are not conclusive, we believe that these findings are worth reporting to the clinical and research communities as they may help guide future research in this domain.

Our regression analyses revealed that the amount of training gain predicted the amount of transfer for CPT, inattention and hyeractivity, school tasks, and matrix reasoning (see Table 3.5). This finding supports our hypothesis and corroborates previous work that the extent to which training is effective is relevant for transfer (Jaeggi, Buschkuehl, Jonides, Shah, et al., 2011). If students do not actually improve throughout training, one would not expect that practice per se would yield any transfer (Solomon & Perkins, 1989). This finding highlights the importance of examining training performance in cognitive training studies. It also suggests that one way of boosting effectiveness of cognitive training interventions is to ensure that participants maintain engagement with training tasks and are able to learn from their practice. Future studies could address the extent to which motivational factors embedded within the training task or different adaptivity parameters or scaffolding are helpful. This issue may be especially important for studies of children with ADHD, as they are more likely to be discouraged when facing challenging cognitive tasks (Seymour et al., 2016).

The effect of training gain on transfer is helpful for interpreting our positive transfer effects on parent ratings of behavior. Specifically, one might question the objectivity of a parent reported measures, arguing that a parent could figure out whether his or her child was in the training or the control group, and that this knowledge would bias questionnaire responses (Cortese et al., 2015). However, though parents may discover which condition their child was in, they are likely to be unaware of whether they actually improved on the training task, as the training was completed in the home and as there was no interaction between the participating families. The fact that training gain was associated with parent reports of behavior suggests that the findings were not likely due to parent expectations.

On the near transfer measure, the object n-back task, there was a significant difference between groups, as predicted. However, the regression analysis revealed no significant relation between the amount of training gain on the object n-back performance. Although we did predict that greater training gains would be associated with greater transfer performance, the lack of such a finding on this particular measure may not, in retrospect, be altogether surprising, because the object n-back task was fixed at a 2-back level. For all participants in the training group, the average n-back level on the very first day of training was 2.4. Thus, even low-performing participants who did not achieve high levels of n-back training still had ample practice at 2-back, providing no advantage to the higher-performing participants on this particular measure.

Although we predicted that the control group would improve relative to the training group on the trivia quiz (the near transfer measure of general knowledge), no significant differences were found between the two groups. One explanation might be that both groups began with high enough general knowledge that this control intervention had no significant effect, or alternatively, that both groups improved equally. As we have no pretest measure of general knowledge, we cannot evaluate these potential explanations.

Our composite measure of working memory yielded no significant differences between groups. The working memory tasks used to form the composite score were digit span and following directions, both of which seem to require active recall rather than updating and recognition, which are primarily involved in n-back, and thus, transfer from n-back to those tasks might be limited (Jaeggi, Studer-Luethi, et al., 2010; Jaeggi, Buschkuehl, Perrig, & Meier, 2010). Furthermore, both working memory outcome measures were verbal tasks while the training task was spatial. One might reasonably expect little transfer across these distinct working memory subsystems, especially also given previous literature that has shown larger correlations between n-back and visual WM tasks as compared to verbal WM tasks (Waris et al., 2017), as well as limited transfer to verbal domains in general (Au et al., 2015; Buschkuehl et al., 2008; Colom et al., 2013). In a recent meta-analysis of n-back cognitive training by Soveri, Antfolk, Karlsson, Salo, and Laine (2017), transfer to working memory tasks yielded smaller effect sizes as compared to the effect sizes found following cognitive training using more traditional working memory training paradigms (Melby-Lervåg & Hulme, 2013; Weicker, Villringer, & Thöne-Otto, 2015; Schwaighofer, Fischer, & Bühner, 2015). However, the fact that an effect seemed to emerge at delayed posttest with the uncorrected *p*-value leaves open the possibility ($BF = 2.32$) that transfer to other working memory domains may be possible, but that a considerable amount of time might be required for such effects to occur or that robust effects might require more training.

We tentatively predicted transfer of n-back training to our composite measure of matrix reasoning especially for children who improved in the task based on previous work with typically developing young adults and children (Jaeggi et al., 2011; Jaeggi, Buschkuehl, Shah, & Jonides, 2014). We also expected to find transfer to school-related tasks, as compared to typically developing children, children with ADHD might suffer from restriction in school-related performance due to their ADHD symptoms. Unfortunately, we found transfer to neither matrix reasoning nor school-related tasks. The failure to observe group differences could reflect the fact that children with ADHD struggle with attention, which is strongly required in tests of matrix reasoning, math, and reading ability. Although we were able to increase attention as a result of our cognitive training, it's possible that we did not increase it enough. The levels achieved by these children with ADHD were lower than those typically achieved by children without ADHD and even certainly lower than typical adult performance. Perhaps with a longer training regimen, transfer to reasoning and school-related skills could be achieved in children with ADHD. Another possible explanation is that performance on the achievement measures require more crystalized knowledge compared to the measures for which we did find effects. As our intervention did not target crystalized knowledge, it is perhaps unsurprising that we did not find improvements in those areas.

Although we found transfer to objective measures of executive functioning, namely inhibition and, to some extent, working memory, we found no transfer to parent-reported executive functioning symptoms of ADHD. One explanation for this lack of transfer may be that, though laboratory and behavioral mesures are related in untrained populations, these relationships are no longer present following training (for example, if participants are learning strategies effective for laboratory tasks that may not apply to everyday behavior). Alternatively, it is possible that there was not enough improvement in inhibition to yield noticeable impact on parent reports of behavior. This second interpretation is consistent with our finding that training gain is correlated with the parent ratings; if training gains were larger, it is possible we would have seen significant improvements in parent ratings. If so, a more effective or longer-term n-back intervention may be necessary to see significant improvements in behavior.

Although the small effect sizes demonstrated here must necessarily temper the interpretation of these findings, the highlight of this study is the finding that sustained attention and inhibitory control can be improved via n-back training. This has the potential to be beneficial for children with ADHD who struggle with inhibition, attention, and hyperactivity. An added benefit of this intervention, compared to CWMT and behavioral therapies, is that it can be completed at home in the absence of a trained professional and can be easily distributed at minimal cost to families of children who struggle with ADHD. Additionally, this study has much to offer theoretically: It provides support for the theory that inhibitory control underlie issues associated with ADHD, namely inattention and hyperactivity. It also offers theoretical support for cognitive training more broadly, and provides insight into the relationship between training gains and transfer.

Limitations

The present study contributes to understanding of cognitive training and to our efforts of ameliorating the difficulties associated with ADHD. However, we acknowledge that our study has limitations. Specifically, outcome measures were all either lab based or parent report. Lab-based measures often lack in ecological validity and thus have limited bearing on everyday life, although the CPT used in our study has been shown to be highly predictive to ADHD symptomatology (Perugini, Harvey, Lovejoy, Sandstrom, & Webb, 2000). Parent report, on the other hand, is rooted in everyday experiences with the child. Thus, parent report measures offer a great deal of ecological validity and clinical relevance, but may not be fully objective. Future work should include more objective assessments of whether improvements resulting from n-back training impact the child’s behavior at school or in the home. Another issue was attrition and dropout. Twenty-one participants (20.79%) did not complete the training or failed to adhere to the training schedule, a rate that seems high on first sight, however, it is lower than what has been reported in studies using similar interventions with non-ADHD samples (e.g., Jaeggi, Buschkuehl, Shah, & Jonides, 2014; Redick et al., 2013) Importantly however, the excluded participants did not vary systematically from the included participants; alleviating concerns regarding selection bias (see Table 3.2).

Conclusion

The present study introduced n-back training as a potential cognitive intervention for children with ADHD. Children with ADHD who completed the training demonstrated improved inhibitory control relative to their peers in the control condition as assessed by lab-based measures.

Our findings have significant implications given that models of ADHD consider inhibitory control to be an underlying core deficit in ADHD (Barkley, 1997). Additionally, the training group's marginally significant reduction in parent-reported symptoms of inattention and hyperactivity has practical relevance: Our data suggest that improving inhibitory control via n-back training may result in decreased ADHD symptoms. Finally, unlike other cognitive interventions that require a trained clinician or researcher to administrator the training, ours was done at home by participants and supervised by parents in an ecologically valid setting. We chose at-home training rather than a laboratory-based training because we wanted to capitalize on one of the primary advantages of computerized cognitive training over or in conjunction with pharmacological or behavioral interventions, namely, that it can be easily distributed and inexpensively deployed. Thus, our findings offer significant practical relevance regarding the development of interventions for children with ADHD.

References

Abikoff, H. B., Jensen, P. S., Arnold, L. L. E., Hoza, B., Hechtman, L., Pollack, S., … Wigal, T. (2002). Observed classroom behavior of children with ADHD: Relationship to gender and comorbidity. *Journal of Abnormal Child Psychology*, *30*(4), 349–359. https://doi.org/10.1023/A:1015713807297

Achenbach, T. M. (1991). Integrative Guide ot the 1991 CBCL/4-18 YSR, and TRF Profiles. *University of Vermont, Department of Psychology Pediatrics*, *108*(1), e14.

Au, J., Buschkuehl, M., Duncan, G. J., & Jaeggi, S. M. (2016). There is no convincing evidence that working memory training is NOT effective: A reply to Melby-Lervåg and Hulme (2015). *Psychonomic Bulletin & Review*, *3*(October), 331–337. https://doi.org/10.3758/s13423-015-0967-4

Au, J., Sheehan, E., Tsai, N., Duncan, G., Buschkuehl, M., & Jaeggi, S. M. (2015). Improving fluid intelligence with training on working memory: a meta-analysis. *Psychonomic Bulletin & Review*, *105*(19), 6829–6833. https://doi.org/10.1073/pnas.0801268105

Banaschewski, T., Roessner, V., Dittmann, R. W., Santosh, P. J., & Rothenberger, A. (2004). Non-stimulant medications in the treatment of ADHD. *European Child and Adolescent Psychiatry, Supplement*, *13*(1), 102–116. https://doi.org/10.1007/s00787-004-1010-x

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65–94. https://doi.org/10.1037/0033-2909.121.1.65

Barkley, R. A., Fischer, M., Smallish, L., & Fletcher, K. (2002). The persistence of attention-deficit/hyperactivity disorder into young adulthood as a function of reporting source and definition of disorder. *Journal of Abnormal Psychology*, *111*(2), 279–289.

https://doi.org/10.1037/0021-843X.111.2.279

Beck, S. J., Hanson, C. a, Puffenberger, S. S., Benninger, K. L., & Benninger, W. B. (2010). A controlled trial of working memory training for children and adolescents with ADHD. *Journal of Clinical Child & Adolescent Psychology*, *39*(October 2010), 37–41. https://doi.org/10.1080/15374416.2010.517162

Bigorra, A., Garolera, M., Guijarro, S., & Hervas, A. (2016). Long-term far-transfer effects of working memory training in children with ADHD: a randomized controlled trial. *European Child & Adolescent Psychiatry*, *25*(8), 853–867.

Brown, L. (2003). Test of Nonverbal Intelligence. *Handbook of Nonverbal Assessment*, 191–221. https://doi.org/10.1007/978-1-4615-0153-4_10

Bullard, S. E., Griss, M., Greene, S., & Gekker, A. (2013). *Encyclopedia of clinical neuropsychology*. *Archives of Clinical Neuropsychology* (Vol. 28). https://doi.org/10.1093/arclin/acs103

Buschkuehl, M., Jaeggi, S. M., Hutchison, S., Perrig-Chiello, P., Däpp, C., Müller, M., … Perrig, W. J. (2008). Impact of Working Memory Training on Memory Performance in Old-Old Adults. *Psychology and Aging*, *23*(4), 743–753. https://doi.org/10.1037/a0014342

Cepeda, N. J., Cepeda, M. L., & Kramer, a F. (2000). Task switching and attention deficit hyperactivity disorder. *Journal of Abnormal Child Psychology*, *28*(3), 213–26. https://doi.org/10.1023/A:1005143419092

Chacko, A., Bedard, a. C., Marks, D. J., Feirsen, N., Uderman, J. Z., Chimiklis, A., … Ramon, M. (2014). A randomized clinical trial of Cogmed Working Memory Training in school-age children with ADHD: A replication in a diverse sample using a control condition. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *55*(3), 247–255.

https://doi.org/10.1111/jcpp.12146

Chacko, A., Feirsen, N., Bedard, A.-C., Marks, D., Uderman, J. Z., & Chimiklis, A. (2013). Cogmed working memory training for youth with ADHD: A closer examination of efficacy utilizing evidence-based criteria. *Journal of Clinical Child & Adolescent Psychology*, *42*(May 2016), 769–783. https://doi.org/10.1080/15374416.2013.787622

Chang, L.-Y., Wang, M.-Y., & Tsai, P.-S. (2016). Diagnostic Accuracy of Rating Scales for Attention-Deficit/Hyperactivity Disorder: A Meta-analysis. *Pediatrics*, *137*(3), e20152749–e20152749. https://doi.org/10.1542/peds.2015-2749

Colom, R., Román, F. J., Abad, F. J., Shih, P. C., Privado, J., Froufe, M., … Jaeggi, S. M. (2013). Adaptive n-back training does not improve fluid intelligence at the construct level: Gains on individual tests suggest that training may enhance visuospatial processing. *Intelligence*, *41*(5), 712–727. https://doi.org/10.1016/j.intell.2013.09.002

Conners, C. K. (1994). Conners Rating Scales. *The Use of Psychological Testing for Treatment Planning and Outcome Assessment.*, 550–578. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=psyc3&NEWS=N&AN=1994-97261-021

Conners, C. K., Epstein, J. N., Angold, A., Klaric, J., Erkanli, A., & Costello, J. E. (2003). Relations between continuous performance test performance measures and ADHD behaviors. *Journal of Abnormal Child Psychology*, *31*(5), 555–562. Retrieved from http://journals.ohiolink.edu/ejc/article.cgi?issn=00910627&issue=v31i0005&article=543_rbcptpmaab%5Cnhttp://journals.ohiolink.edu.proxy.antioch.edu/ejc/article.cgi?issn=00910627&issue=v31i0005&article=543_rbcptpmaab%5Cnhttp://journals.ohiolink.edu/ejc/article.

Conners, C. K., Sitarenios, G., Parker, J. D. A., & Epstein, J. N. (1998). The revised Connors'

Parent Rating Scale (CPRS-R): factor structure, reliability, and criterion validity. *Journal of Abnormal Child Psychology*, *26*(4), 257–268. https://doi.org/10.1023/A

Conners, C. K., Staff, M. H. S., Connelly, V., Campbell, S., MacLean, M., & Barnes, J. (2000). Conners' Continuous Performance Test II (CPT II V. 5). *Multi-Health Systems Inc*, *29*(1), 175–196. https://doi.org/10.1207/s15326942dn2901_9

Conners, K. C. (2001). *Conners' rating scale-revised (CRS-R)* (5th ed.). North Tonawande, NY: Multi-Health Systems, Inc.

Corkum, P. V, & Siegel, L. S. (1993). Is the Continuous Performance Task a valuable research tool for use with children with Attention-Deficit-Hyperactivity Disorder? *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *34*(7), 1217–1239. https://doi.org/10.1111/j.1469-7610.1993.tb01784.x

Cornoldi, C., Barbieri, A., Gaiani, C., & Zocchi, S. (1999). Strategic memory deficits in attention deficit disorder with hyperactivity participants: The role of executive processes. *Developmental Neuropsychology*, *15*(1), 53–71. https://doi.org/10.1080/87565649909540739

Cortese, S., Ferrin, M., Brandeis, D., Buitelaar, J., Daley, D., Dittmann, R. W., … Sonuga-Barke, E. J. S. (2015). Cognitive training for attention-deficit/hyperactivity disorder: Meta-analysis of clinical and neuropsychological outcomes from randomized controlled trials. *Journal of the American Academy of Child and Adolescent Psychiatry*, *54*(3), 164–174. https://doi.org/10.1016/j.jaac.2014.12.010

DSM-IV Diagnostic and Statistical Manual of Mental Disorder. (1994). *American Psychiatric Organization*. https://doi.org/10.1073/pnas.0703993104

DuPaul, G., & Stoner, G. (2014). *ADHD in the schools* (3rd ed.). New York, New York, USA:

Guilford Press.

Enge, S., Behnke, A., Fleischhauer, M., Küttler, L., Kliegel, M., & Strobel, A. (2014). No evidence for true training and transfer effects after inhibitory control training in young healthy adults. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *40*(4), 987–1001. https://doi.org/10.1037/a0036165

Fabiano, G. A., Pelham, W. E., Coles, E. K., Gnagy, E. M., Chronis-Tuscano, A., & O’Connor, B. C. (2009). A meta-analysis of behavioral treatments for attention-deficit/hyperactivity disorder. *Clinical Psychology Review*, *29*(2), 129–140. https://doi.org/10.1016/j.cpr.2008.11.001

Faraone, S. V., Biederman, J., & Mick, E. (2005). The age-dependent decline of attention deficit hyperactivity disorder: a meta-analysis of follow-up studies. *Psychological Medicine*, *36*(2), 159. https://doi.org/10.1017/S003329170500471X

Friso-Van Den Bos, I., Van Der Ven, S. H. G., Kroesbergen, E. H., & Van Luit, J. E. H. (2013). Working memory and mathematics in primary school children: A meta-analysis. *Educational Research Review*, *10*, 29–44. https://doi.org/10.1016/j.edurev.2013.05.003

Gathercole, S. E., Durling, E., Evans, M., Jeffcook, S., & Stone, S. (2008). Working memory abilities and children’s performance in laboratory analogues of classroom activities. *Applied Cognitive Psychology*, *22*, 1019–1037. https://doi.org/10.1002/acp

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). Behavior rating inventory of executive function. *Child Neuropsychology : A Journal on Normal and Abnormal Development in Childhood and Adolescence*, *6*(3), 235–8. https://doi.org/10.1076/chin.6.3.235.3152

Grenwelge, C. H. (2009). Test Review: Woodcock, R. W., Schrank, F. A., Mather, N., &

McGrew, K. S. (2007). Woodcock-Johnson III Tests of Achievement, Form C/Brief Battery. Rolling Meadows, IL: Riverside. *Journal of Psychoeducational Assessment*, *27*(4), 345–350. https://doi.org/10.1177/0734282908327944

Hochberg, Y., & Benjamini, Y. (1990). More powerful procedures for multiple statistical significance testing. *Stat Med*, *9*, 811–818.

Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, *12*(4), 9–15. https://doi.org/10.1111/j.1467-7687.2009.00848.x

Hsu, N. S., Buschkuehl, M., Jonides, J., & Jaeggi, S. M. (2013). Potential mechanisms underlying working memory training and transfer. In *Psychonomic Society Annual Meeting*. Toronto.

Hsu, N. S., Jaeggi, S. M., & Novick, J. M. (2017). A common neural hub resolves syntactic and non-syntactic conflict through cooperation with task-specific networks. *Brain and Language*, *166*, 63–77. https://doi.org/10.1016/j.bandl.2016.12.006

Hussey, E. K., & Novick, J. M. (2012). The benefits of executive control training and the implications for language processing. *Frontiers in Psychology*, *3*(May), 158. https://doi.org/10.3389/fpsyg.2012.00158

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Shah, P. (2011). Working memory training in typically developing children and children with Attention Deficit Hyperactivity Disorder: evidence for plasticity in executive control processes. In *Eighteenth Annual Cognitive Neuroscience Society Meeting*. San Francisco, CA.

Jaeggi, S. M., Buschkuehl, M., Jonides, J., Shah, P., Morrison, A. B., & Chein, J. M. (2011). Short-and long-term benefits of cognitive training. *Proceedings of the National Academy of*

Sciences, *108*(25), 46–60. https://doi.org/10.1073/pnas.1103228108

Jaeggi, S. M., Buschkuehl, M., Perrig, W. J., & Meier, B. (2010). The concurrent validity of the N-back task as a working memory measure. *Memory*, *18*(4), 394–412. https://doi.org/10.1080/09658211003702171

Jaeggi, S. M., Buschkuehl, M., Shah, P., & Jonides, J. (2014). The role of individual differences in cognitive training and transfer. *Memory & Cognition*, *42*, 464–80. https://doi.org/10.3758/s13421-013-0364-z

Jaeggi, S. M., Studer-Luethi, B., Buschkuehl, M., Su, Y. F., Jonides, J., & Perrig, W. J. (2010). The relationship between n-back performance and matrix reasoning - implications for training and transfer. *Intelligence*, *38*(6), 625–635. https://doi.org/10.1016/j.intell.2010.09.001

Karatekin, C., & Asarnow, R. F. (1998). Working memory in childhood-onset schizophrenia and attention-deficit/hyperactivity disorder. *Psychiatry Research*, *80*(2), 165–176. https://doi.org/10.1016/S0165-1781(98)00061-4

Katz, B., Jaeggi, S., Buschkuehl, M., Stegman, A., & Shah, P. (2014). Differential effect of motivational features on training improvements in school-based cognitive training. *Frontiers in Human Neuroscience*, *8*, 242. https://doi.org/10.3389/fnhum.2014.00242

Klauer, K. J., & Phye, G. D. (2008). Inductive Reasoning: A Training Approach. *Review of Educational Research*, *78*(1), 85–123. https://doi.org/10.3102/0034654307313402

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlström, K., … Westerberg, H. (2005). Computerized training of working memory in children with ADHD: A randomized, controlled trial. *Journal of the American Academy of Child & Adolescent Psychiatry*, *44*, 177–186. https://doi.org/10.1097/00004583-200502000-00010

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology*, *24*(6), 781–791. https://doi.org/10.1076/jcen.24.6.781.8395

McInnes, A., Humphries, T., Hogg-Johnson, S., & Tannock, R. (2003). Listening comprehension and working memory are impaired in Attention-Deficit Hyperactivity Disorder irrespective of language impairment. *Journal of Abnormal Child Psychology*, *31*(4), 427–443.

Mcvay, J. C., & Kane, M. J. (2012). Why does working memory capacity predict variation in reading comprehenion? On the influence of mind wandering and executive attention. *Journal of Experimental Psychology General*, *141*(2), 302–320. https://doi.org/10.1037/a0025250.Why

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*. https://doi.org/10.1037/a0028228

Mezzacappa, E., & Buckner, J. C. (2010). Working memory training for children with attention problems or hyperactivity: a school-based pilot study. *School Mental Health*, *2*(4), 202–208. https://doi.org/10.1007/s12310-010-9030-9

Moffitt, T. E., Houts, R., Asherson, P., Belsky, D. W., Corcoran, D. L., Hammerle, M., … Caspi, A. (2015). Is adult ADHD a childhood-onset neurodevelopmental disorder? Evidence from a four-decade longitudinal cohort study. *American Journal of Psychiatry*, *172*(10), 967–977. https://doi.org/10.1176/appi.ajp.2015.14101266

Pelham, W. E., Smith, B. H., Evans, S. W., Bukstein, O., Gnagy, E. M., Greiner, A. R., & Sibley, M. H. (2017). The Effectiveness of Short- and Long-Acting Stimulant Medications for Adolescents With ADHD in a Naturalistic Secondary School Setting. *Journal of Attention Disorders*, *21*(1), 40–45. https://doi.org/10.1177/1087054712474688

Perugini, E. M., Harvey, E. a, Lovejoy, D. W., Sandstrom, K., & Webb, a H. (2000). The predictive power of combined neuropsychological measures for attention-deficit/hyperactivity disorder in children. *Child Neuropsychology : A Journal on Normal and Abnormal Development in Childhood and Adolescence*, *6*(2), 101–114. https://doi.org/10.1076/chin.6.2.101.7059

Pineda, D., Ardila, A., Rosselli, M., Cadavid, C., Mancheno, S., & Mejia, S. (1998). Executive dysfunctions in children with attention deficit hyperactivity disorder. *International Journal of Neuroscience*, *96*(3–4), 177–196. https://doi.org/http://dx.doi.org/10.3109/00207459808986466

Polanczyk, G. V., Willcutt, E. G., Salum, G. A., Kieling, C., & Rohde, L. A. (2014). ADHD prevalence estimates across three decades: An updated systematic review and meta-regression analysis. *International Journal of Epidemiology*, *43*(2), 434–442. https://doi.org/10.1093/ije/dyt261

Ramani, G. B., Jaeggi, S. M., Daubert, E. N., & Buschkuehl, M. (2017). Domain-specific and domain-general training to improve kindergarten children’s mathematics. *Journal of Numerical Cognition*, *3*(2), 468–495. https://doi.org/10.5964/jnc.v3i2.31

Raven, J. (2000). The Raven’s Progressive Matrices: change and stability over culture and time. *Cognitive Psychology*, *41*, 1–48. https://doi.org/10.1006/cogp.1999.0735

Redick, T. S., Shipstead, Z., Harrison, T. L., Hicks, K. L., Fried, D. E., Hambrick, D. Z., … Engle, R. W. (2013). No evidence of intelligence improvement after working memory training: A randomized, placebo-controlled study. *Journal of Experimental Psychology: General*, *142*(2), 359–379. https://doi.org/10.1037/a0029082

Reeve, W. V., & Schandler, S. L. (2001). Frontal lobe functioning in boys with attention deficit hyperactivity disorder. *Adolescence, 36*(144), 749.

Roberts, G., Quach, J., Spencer-smith, M., Anderson, P. J., Gathercole, S., Gold, L., … Wake, M. (2016). Academic outcomes 2 years after working memory training for children with low working memory: a randomized clinical trial. *JAMA Pediatrics*, *170*(5), 1–10. https://doi.org/10.1001/jamapediatrics.2015.4568

Rubia, K., Alegria, A. A., Cubillo, A. I., Smith, A. B., Brammer, M. J., & Radua, J. (2014). Effects of stimulants on brain function in attention-deficit/hyperactivity disorder: A systematic review and meta-analysis. *Biological Psychiatry*, *76*(8), 616–628. https://doi.org/10.1016/j.biopsych.2013.10.016

Schwaighofer, M., Fischer, F., & Bühner, M. (2015). Does Working Memory Training Transfer? A Meta-Analysis Including Training Conditions as Moderators. *Educational Psychologist*, *50*(2), 138–166. https://doi.org/10.1080/00461520.2015.1036274

Seymour, K. E., Macatee, R., & Chronis-Tuscano, A. (2016). Frustration tolerance in youth with ADHD. *Journal of Attention Disorders*, 1087054716653216. https://doi.org/10.1177/1087054716653216

Shavlev, L., Tsal, Y., & Mevorach, C. (2002). *Computerized progressive attentional training (CPAT) program: Effective direct intervention for children with ADHD. Dissertation*.

Shipstead, Z., Hicks, K. L., & Engle, R. W. (2012). Cogmed working memory training: Does the evidence support the claims? *Journal of Applied Research in Memory and Cognition*, *1*(3), 185–193. https://doi.org/10.1016/j.jarmac.2012.06.003

Solomon, G., & Perkins, D. N. (1989). Rocky Roads to Transfer: Rethinking Mechanisms of a Neglected Phenomenon. *Educational Psychologist*, *24*(2), 113–142. https://doi.org/10.1207/s15326985ep2402

Sonuga-Barke, E. J. S., Brandeis, D., Coreste, S., Daley, D., Ferrin, M., Holtmann, M., … Coghill, D. (2013). Nonpharmacological Interventions for ADHD: Systematic Review and Meta-Analyses of Randomized Controlled Trials of Dietary and Psychological Treatments. *American Journal of Psychiatry*, (February 2016).

Sonuga-Barke, E. J. S., Dalen, L., Daley, D., & Remington, B. (2002). Are Planning, working memory, and inhibition associated with individual differences in preschool ADHD symptoms? *Developmental Neuropsychology*, *21*(3), 255–272.

Soveri, A., Antfolk, J., Karlsson, L., Salo, B., & Laine, M. (2017). Working memory training revisited: A multi-level meta-analysis of n-back training studies. *Psychonomic Bulletin and Review*, *24*(4), 1077–1096. https://doi.org/10.3758/s13423-016-1217-0

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology (2006)*, *59*(4), 745–759. https://doi.org/10.1080/17470210500162854

Toomey, S. L., Sox, C. M., Rusinak, D., & Finkelstein, J. a. (2012). Why do children with ADHD discontinue their medication? *Clinical Pediatrics*, *51*(8), 763–9. https://doi.org/10.1177/0009922812446744

Visser, S. N., Danielson, M. L., Bitsko, R. H., Holbrook, J. R., Kogan, M. D., Ghandour, R. M., … Blumberg, S. J. (2014). Trends in the parent-report of health care provider diagnosed and medicated ADHD: United States, 2003-2011. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*(1), 34–46. https://doi.org/10.1002/dev.21214.Developmental

Wagenmakers, E. J., Love, J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., … Morey, R. D. (2017). Bayesian inference for psychology. Part II: Example applications with JASP.

Psychonomic Bulletin and Review, 1–19. https://doi.org/10.3758/s13423-017-1323-7

Waris, O., Soveri, A., Ahti, M., Hoffing, R. C., Ventus, D., Jaeggi, S. M., … Laine, M. (2017). A latent factor analysis of working memory measures using large-scale data. *Frontiers in Psychology*, *8*(JUN), 1–14. https://doi.org/10.3389/fpsyg.2017.01062

Wechsler, D. (2003). Wechsler intelligence scale for children–Fourth Edition (WISC-IV). *San Antonio, TX: The Psychological Corporation*. Retrieved from https://www.pearsonassessments.com/HAIWEB/Cultures/en-us/Productdetail.htm?Pid=015-8979-044&Mode=resource%5Cnhttp://www.pearsonclinical.com/psychology/products/100000310/wechsler-intelligence-scale-for-children-fourth-edition-wisciv.html?Pid=015-8979-044&Mo

Weicker, J., Villringer, A., & Thöne-Otto, A. (2015). Can Impaired Working Memory Functioning Be Improved By Training? A Meta-Analysis With a Special Focus on Brain Injured Patients. *Neuropsychology*. https://doi.org/10.1037/neu0000227

Westerberg, H., Hirvikoski, T., Forssberg, H., & Klingberg, T. (2004). Visuo-spatial working memory span: A sensitive measure of cognitive deficits in children with ADHD. *Child Neuropsychology*, *10*(September), 155–161. https://doi.org/R2QM3DXW5LC83BXP [pii]\r10.1080/09297040409609806

White, H. a, & Shah, P. (2006). Training attention-switching ability in adults with ADHD. *Journal of Attention Disorders*, *10*(1), 44–53. https://doi.org/10.1177/1087054705286063

Wolraich, M., Brown, L., Brown, R., DuPaul, G., Earls, M., & Heidi, F. (2011). ADHD: Clinical practice guideline for the diagnosis, evaluation, and treatment of Attention-Deficit/Hyperactivity Disorder in children and adolescents. *American Academy of*

Pediatrics, *128*(5), 1–16. https://doi.org/10.1542/peds.2011-2654

Woodcock, R. W., McGrew, K. S., & Mather, N. (2003). *Woodcock-Johnson III Tests of Achievement*. *Riverside Publishing*. Retrieved from http://www.iapsych.com/wj3ewok/LinkedDocuments/Buros%5CnDS%5Cnreview%5Cncopy.pdf

CHAPTER 4

Fostering Persistence among Children with ADHD:

Can a Motivation Intervention Help?

Attention Deficit Hyperactivity Disorder (ADHD) is a developmental disorder characterized by inattention, hyperactivity, and impulsive behavior, Approximately 3–5% of all children are affected (*DSM-V Diagnostic and Statistical Manual of Mental Disorder*, 2013, Pastor & Reuben, 2002); with over 50 million children enrolled in US schools, the number of US school children struggling with ADHD is approximately 1.5–2.5 million (NCES, 2016). ADHD symptoms usually arise early in life, typically before the age of seven. They generally continue through adolescence and persist into adulthood for 30–60% of individuals with the condition (Barkley, 1997; Barkley, Fischer, Smallish, & Fletcher, 2002; Faraone, Biederman, & Mick, 2005). Many predominant theories of ADHD suggest an underlying impairment in motivational style (Sonuga-Barke, 2002), which may contribute to the fact that, in addition to struggling with the specific symptoms of ADHD, children with ADHD tend to face poor academic trajectories. Approximately 80% have academic performance problems and a higher incidence of grade retention and dropping out of school compared to children without ADHD (DuPaul & Stoner, 2014).

Prior literature suggests that maladaptive motivational beliefs and behaviors contribute to the academic underachievement characteristic of children with ADHD. For example, children with ADHD may be more likely than their typically developing peers to endorse the idea that cognitive abilities are fixed (Dunn & Shapiro, 1999). Individuals with such beliefs are more likely to have lower self-efficacy, to avoid challenging cognitive tasks, to be less persistent when tasks become difficult, and to endorse performance rather than mastery goal orientations (Dweck & Leggett, 1988). Thus, there is a strong, practical need for the development of effective interventions to mitigate challenges associated with these motivational patterns. Although pharmacological and behavioral interventions exist, interventions targeting the motivational issues associated with ADHD—mindset, self-efficacy, and persistence—may lead to increased motivation and ultimately, contribute to academic success.

Motivational Variables and Academic Success

Educational and psychological research has investigated individual differences in children's motivational beliefs and behaviors in order to understand the choices that people make and how those relate to success. Variables of interest include children's beliefs about the nature of intelligence, goal-orientations, perceptions of their academic abilities, capacity for emotional control, and willingness to persist. According to theories on mindsets, children tend to harbor one of two core beliefs on the malleability of intelligence: that intelligence is *fixed* and unchangeable, or that it has the potential for *growth* with effort and instruction. Although children can fall along a spectrum between the two mindsets, and mindsets are often domain dependent (Thomas & Sarnecka, 2015), this theory provides a framework for understanding how children interpret feedback and set goals. Generally speaking, having a fixed mindset is linked to endorsement of *performance goals*, in which children focus on appearing "smart" and receiving positive evaluations from others. Conversely, children with a growth mindset are more likely to have *mastery goals*, in which their aim is to develop competence and master new things (Dweck, 1986; Pintrich, 2000). A closely related predictor of motivational patterns is self-efficacy—or a child's confidence in his or her performance capabilities, which is important because those with high self-efficacy are more likely to strive for achievement (Zimmerman, 2000). Researchers are also interested in how effectively children are able to manage their emotions when they are *actually* faced with a challenging task. Studies demonstrate that children's responses can be broadly categorized along two dimensions: *helpless* versus *mastery-oriented.* A helpless response is characterized by self-defeating behavior, such as increased negative emotions and endorsement of work-avoidant strategies. Children with a mastery-oriented response, on the other hand, are able to maintain emotional control and show high persistence in the face of setbacks (Blackwell & Trzesniewski, 2007; Dweck, 1986). Research on motivation frameworks indicates that mindsets, goal-orientations, self-efficacy, and behavior patterns are highly interrelated. Children who hold a fixed mindset, performance goals, and low self-efficacy tend to display helplessness towards academic challenges, whereas children with a growth mindset, mastery goals, and high self-efficacy show a mastery-orientation (Dweck, 1986).

Not surprisingly, having a growth mindset, high self-efficacy, and mastery orientation translates to direct benefits for learning and academic performance. Across elementary school and junior high school, students with a growth mindset tend to receive higher grades than their peers. They outperform students with a fixed mindset when their scores are averaged across multiple subject matters, such as language arts, mathematics, social studies, and science (Haimovitz, Wormington, & Corpus, 2011). Similarly, longitudinal studies have revealed that students who endorse a growth mindset in seventh grade receive better mathematics grades over the course of junior high than those with a fixed mindset, regardless of initial mathematics ability (Blackwell & Trzesniewski, 2007; Cury, Elliot, Da Fonseca, & Moller, 2006). Related studies have also found self-efficacy to be a powerful predictor of school achievement. For example, research on student performance in seventh and eighth grade English classes shows that self-efficacious students attain higher scores across all types of graded work, ranging from in-class activities and homework, tests and quizzes, and essays and reports (Pintrich & de Groot, 1990). Another longitudinal study with high school students found that those with high self-efficacy at the beginning of the semester achieved better final grades in their social studies class than their peers with low self-efficacy. Moreover, the predictive value of self-efficacy remained even after accounting for students' performance in their prior social studies course (Zimmerman, Bandura, & Martinez-Pons, 1992). This evidence suggests that fostering a growth mindset, mastery goals, self-efficacy, and mastery orientation are worthy goals, especially for children with ADHD who may have significant struggles in those areas.

Motivation in Children with ADHD

Given the importance of motivational beliefs and behaviors to academic success, it is critical to investigate the role of these variables in children with ADHD. While literature on this topic is limited, findings provide some evidence that children with ADHD tend to exhibit maladaptive motivational patterns (Dunn & Shapiro, 1999). For example, children with ADHD are more likely to endorse a fixed mindset and choose performance goals over mastery goals on self-report measures, when compared to their typically developing peers. They also tend to report a significantly lower sense of self-confidence in their intellectual capacity and academic abilities (Tabassam & Grainger, 2002). Moreover, after experiencing failure on problem-solving tasks, children with ADHD demonstrate reduced persistence, are less willing to continue solving problems, and report a preference for easier problems (Dunn & Shapiro, 1999). Parent and teacher reports, unfortunately, also characterize children with ADHD as having a problematic motivational style. They indicate that children with ADHD show limited intrinsic motivation, diminished persistence, less enjoyment of learning, and lower self-expectations than typically developing children. Adult informants also suggest that children with ADHD favor less challenging work, show a greater reliance on external feedback to evaluate their performance, and have strong desire to be viewed by others as high performing (Carlson, Booth, Shin, & Canu, 2002). Together, this accumulating evidence suggests that children with ADHD tend toward endorsing a fixed mindset, performance goals, poor self-efficacy, and helpless motivational behavior, and point to motivational variables, which are potentially modifiable (see below), as key targets for intervention work.

Motivational Interventions

Interventions aimed at altering beliefs about the malleability of intelligence, self-efficacy, and emotional control have been well researched, with promising results. In several randomized control trials, students who were taught that intelligence could be developed and that the brain could change with learning were more likely to endorse a growth mindset (Aronson, Fried, & Good, 2002; Blackwell et al., 2007; Yeager et al., 2016), to report greater enjoyment of learning (Aronson et al., 2002), and to be spontaneously identified by teachers as showing improvement in motivation and persistence (Blackwell et al., 2007), when compared to peers in active control groups. Moreover, students in the experimental groups showed better grade trajectories in junior high (Blackwell et al., 2007), received higher standardized test scores in high school (Good, Aronson, & Inzlicht, 2003), and demonstrated higher GPA attainment in high school (Yeager et al., 2016) and in college (Aronson et al., 2002). Similar results have been found for interventions that focus on cognitive strategies for coping with frustration and increasing persistence. Across middle school, high school, and college, students who were taught to interpret difficulty as a cue that a task is important rather than impossible are more likely to describe themselves as school-focused and engage in study activities to attain school success (Oyserman, 2014). However, motivation interventions are not universally beneficial. Across multiple studies, “at-risk” students seemed to benefit the most (Schwartz, Cheng, Salehi, & Wieman, 2016). As children with ADHD are particularly at risk for having poor motivational patterns, they may have the potential to benefit greatly from such an intervention.

The Present Study

The goal of our study was to test whether the persistence of children with ADHD could be improved by teaching them to develop a growth mindset and a stronger sense of self-efficacy, and to equip them with strategies to help them persist in the face of frustration.

Method

Participants

Seventy-one participants and their parents were recruited and enrolled into the study. The majority of participants were recruited through use of an online recruiting platform called StudyKIK for clinical trials that reaches potential participants via social media. Participants were also recruited through outreach to professionals, schools, and organizations in the community that work with the target population. Flyers were also distributed at public locations in the nearby community. Finally, we made use of snowball sampling, or the referral of new participants by current participants.

All adult participants (i.e., parents) were contacted directly by phone or email to discuss the study in depth, go over consent, address questions or concerns, and to determine eligibility. Child participants were considered eligible for the study if they were between the ages of seven–14, were diagnosed with ADHD, were fluent in English, and had an English-speaking parent who was also able to participate. Severe autism was an exclusion criteria.

Measures

Parent Measures. The following measures were completed by parents prior to the start of the intervention.

Demographic Information. Parents reported on multiple demographic characteristics for both themselves and their child(ren). These included the parents' gender and ethnicity, and the child's gender, age, and ethnicity. Parents were also asked to report on their own level of education, their income, the family's living situation, and the child's school.

Diagnostic Information. Parents were asked to confirm their child's clinical diagnosis of ADHD, then report on other aspects of the diagnosis. Parents detailed the age their child received the ADHD diagnosis, listed any comorbidities their child had been diagnosed with, and indicated whether their child was currently taking any stimulant medication.

The Behavior Rating Inventory of Executive Function, Second Edition (BRIEF2). To assess executive functioning in the child participants, the BRIEF2 questionnaire (Gioia, Isquith, Guy, & Kenworthy, 2005) was completed by the parents. Parents were given a battery of statements concerning their child's executive functioning abilities, to which they had to respond on a three-point Likert scale ranging from "Never" to "Often." Examples of the statements include "Has explosive, angry outbursts" or "Has a short attention span." The 63-item measure is made up of nine clinical scales, which form three composite scores: behavior regulation, emotion regulation, and cognitive regulation. The measure has been widely used and tested for construct validity (Jacobson, Pritchard, Koriakin, Jones, & Mahone, 2016).

Child Measures. The following measures were administered at pretest, posttest, and at follow up.

Theories of Cognitive Abilities Survey. The Theories of Cognitive Abilities Survey (Dweck, 1999) assesses participants' ideas about intelligence using a three-item self-report questionnaire. The children responded to statements such as "You have a certain amount of intelligence, and you really can't do much to change it" by using a four-point Likert scale ranging from "strongly agree" to "strongly disagree." Higher score indicate more of a growth mindset. The reliability in our sample was Cronbach's $\alpha = 0.67$.

Need for Cognition. On this four-item questionnaire adapted from (Cacioppo, Petty, & Kao, 1984), children were asked how much they identify with statements relating to thinking and cognitive engagement. The children responded to statements such as "I like to spend a lot of time and energy thinking about something" using a four-point Likert scale ranging from "strongly agree" to "strongly disagree." The dependent measure is an average score from the four items, where a higher score indicates a greater need for cognition. The reliability in our sample was Cronbach's $\alpha = 0.64$.

Grit Scale. Children were asked to report on perseverance and grit using the eight-item self-report Grit-S questionnaire. The Grit-S is an adaptation of the original Grit measure, shorted by (Duckworth & Quinn, 2009) for efficiency and found to be psychometrically valid. The reliability in our sample was Cronbach's $\alpha = 0.58$. Child participants designated how much they identify with statements such as "Setbacks don't discourage me" by using a five-point Likert scale ranging from "Very much like me" to "Not like me at all." The dependent measure is an average score across items, where a higher score indicates greater grit.

Spatial Persistence Task. Perseverance was assessed by asking children to replicate patterns using either four or nine painted blocks (Dweck, 2010a). They were first shown by research personnel how use the blocks to create an easy pattern with four blocks. They were then asked to attempt two easier, four-block patterns followed by two harder, nine-block patterns themselves (see Figure 4.1). The children were then given a choice of either an additional easier block pattern that they would "probably be able to complete" or a harder block pattern "that might help them learn." Perseverance in this task was determined by whether the child would select the harder, nine-block puzzle or the easier, four-block puzzle. After the initial example, the children were not given any assistance from research personnel during this task. If the child struggled and asked for help, they were encouraged to "keep trying" or "do your best." If the child was unable to replicate a pattern and wanted to give up, they would receive the next pattern. There were two sets of patterns that were counterbalanced across participants, such that some would complete set A at pretest, set B at posttest, and set A again at follow-up, whereas others would complete set B at pretest, set A at posttest, and set B again at follow-up.

Figure 4.1. Child completing a "harder," 9-block puzzle during the spatial persistence task.

Verbal Persistence Task. Perseverance was also assessed using a verbal persistence task developed for this study. This task involved answering trivia questions, math questions, word scrambles and analogies. Based on the spatial persistence task, participants were asked to complete one easier page with 10 questions and then one harder page of 10 questions. The child was then given the choice of a third page with 10 questions more like the first (easier) page or the second (harder) page. Perseverance in this task was determined by whether the child would pick the easier page or the harder page. There were two versions of the task that were counterbalanced across participants, such that some would complete version A at pretest, version B at posttest, and version A again at follow-up, whereas others would complete version B at pretest, version A at posttest, and version B again at follow-up.

Procedures

The overall structure of the intervention was as follows: Cohorts of children were randomly assigned to a condition (motivation or study skills) and parents completed their surveys prior to the first testing day. The first day included a pretest session for the children and an orientation lesson for the parents. The following four sessions were the child intervention lessons, followed by a final posttest session. Approximately five months following completion of the intervention, children and parents were invited back for an optional follow-up session. Our procedures were approved by the Institutional Review Board. All parents provided written informed consent, and all children provided informed assent. Families were compensated $20 for their participation.

Pre- and Post-testing. Each child met one-on-one with a researcher to complete the pretest measures described above. During the child pretest session, parents met with the two researchers conducting the intervention. These parent sessions were framed as an orientation meeting to provide parents with an overview of the concepts their child would be working with and some academic literature behind these concepts, while also providing parents with a chance to think about and share strategies they could use to effectively support their child throughout the intervention and beyond. As such, both conditions contained researcher-led presentation sessions, but also encouraged parent-driven discussion. Researchers set a conversational and inviting tone, welcoming the sharing of individual stories and strategies, but also guided the flow of the discussion by emphasizing the key strategies and takeaways common across all sessions. For their future reference, parents were given information packets containing the discussed relevant research as well as additional resources (see Appendices II and III).

Both conditions contained an overview of the respective core concepts — promoting either motivational beliefs or effective study skills — that would be covered in student sessions over the next two weeks. Researchers also promoted conversation between parents on the core topics of the session intervention. The motivation condition parents were introduced to Dweck's research on growth mindset and research demonstrating that mindsets can be changed. Parent discussion focused on specific ways of praising children in order to reward effort and motivation. The study skills condition parent sessions discussed useful study strategies. Parents discussed their own priorities using an activity that the students would later experience as well.

After completion of the intervention, child participants returned to complete the same measures again at posttest with the same researcher. There was no parent session during child posttest. The researchers who conducted the pre- and posttest sessions were blind to participant condition.

Follow-up testing and parent focus groups. Approximately five months following completion of the intervention (range = 3–12 months), the families were invited to return to the lab for a follow-up session. During this session, the children completed the same measures as at pre- and posttest. These were re-administered in order to test whether any changes emerged after some time had passed, during which participants may have internalized more lessons from the intervention.

During this session, parents participated in a semi-structured focus group. These were groups of one–four parents, depending on their availability. To assess the parents' perceptions of the intervention and its impact on their children, they were asked questions such as "can you tell us about your child's experience participating in our session" and "since the intervention has passed, have you noticed any changes in your child's habits or behavior." After the interview, parents were given the GRIT questionnaire and asked to fill it out as it pertained to their children. When the questionnaire was completed, they were then asked if any questions in the questionnaire particularly resonated with anyone and if something rang very true for their child. The interview sessions were recorded and transcribed for qualitative analysis.

Intervention Lessons. Participants were randomly assigned to either the motivation or study skills intervention group. Both intervention groups were conducted by two researchers over four 50-minute sessions that took place twice a week for two consecutive weeks. Group sizes were typically three to five participants. Each session began with introductions and icebreakers to build rapport, contained a discussion and activity, and engaged students artistically by creating a small project they could take home. Session four for each group ended with a brief review of all the topics discussed. Full lesson plans are available in Appendices IV and V.

Motivational Intervention. The motivation intervention focused on building growth mindset, setting mastery goals, persisting in the face of frustration, and building up one's sense of self-efficacy. Researchers focused on encouraging students to persist in the face of challenge and reframing problems as opportunities to grow their brain or improve their skills. A path metaphor was used to frame obstacles as roadblocks that were part of a lifelong journey (Landau, Oyserman, Keefer, & Smith, 2014). During the first lesson, the motivation group watched a video (Class Dojo, 2016) and discussed growth mindset and the possibility of gradual improvement and setting mastery goals. Participants shared examples of times they had found something difficult, decided it was important, persisted or practiced, and improved as a result. The second lesson built on these concepts by relating achievement to effort and neural changes in the brain. As a part of this lesson, participants molded a neuron from beeswax. The third lesson addressed strategies for keeping calm and persisting in the face of frustration. Participants watched a video discussing self-esteem and self-acceptance then discussed these ideas as a group. Finally, the fourth lesson discussed creativity in ADHD and encouraged participants to leverage their creativity to think of different strategies for overcoming obstacles.

Study Skills Control Intervention. The control study skills intervention focused on supplying students with tools for effective studying. When encouraging participants, researchers focused on finding a solution for the specific scenario. Although study tips were brought up for formal school learning, researchers also encouraged students to view "studying" as practicing hobbies or building skills towards a non-academic goal. The first lesson opened the discussion on studying by describing the physical space participants had for studying or working on schoolwork. As a group, participants and researchers discussed external distractions that could come up in the space, followed by a discussion of internal distractions that might hinder getting work done (e.g., hunger or boredom), and ending with a short game to demonstrate how multitasking is also a distraction. The second lesson provided opportunities to share and practice note-taking strategies, such as highlighting or drawing flow charts and outlines. Expanding broader than individual study sessions, lesson three discussed spacing study sessions apart and interleaving subjects for better long-term memory (Bjork & Bjork, 2011). Finally, lesson four took another look at schedule design by discussing priorities in life. Students watched a video about how big rocks and small pebbles arranged in a jar could be used as a metaphor for prioritizing different things in life, then proceeded to discuss and identify their own “big rocks” (Litmus Heroes, 2014)

Hypotheses and Analysis Plan

We hypothesized that participants from both groups would benefit from our interventions, but we predicted that participants in the motivation intervention would demonstrate larger gains on our measures of motivation and persistence. At follow up, we predicted that parents of children in the motivation group would be more likely to report changes in their children’s persistence and beliefs about intelligence and self-efficacy, whereas we predicted that parents of children in the study skills group would be more likely to report changes in task-specific behaviors such as note-taking skills.

Quantitative Analyses. Quantitative analyses were conducted using IBM SPSS Statistics Version 24 and JASP Version 0.8.5.1. First, we examined whether there were any significant intervention group differences on key demographic variables. The same comparisons were conducted for included versus excluded participants and for the full sample versus the smaller sample at follow-up. Then, the two intervention groups were compared on their pretest performance to test for any baseline differences. Next, the outcome measures were examined together using an exploratory factor analysis in order to create composite variables where appropriate, reducing the overall number of comparisons. In order to estimate the impact of our intervention, the quantitative outcome measures were analyzed using Analysis of Covariance (ANCOVA). Each outcome variable was compared between groups at posttest and at follow up with the pretest score as a covariate.

Qualitative Analyses. Qualitative data were analyzed using MAXQDA Analytics Pro (VERBI Software, 2016). Interview and focus group data were first transcribed then coded. Descriptive coding was used in order to summarize central themes found within the data.

Results

Quantitative Analyses

A total of 71 participants enrolled in the study. Of those, 12 were not included in the final analyses. Eight failed to complete the intervention, two were excluded due to poor compliance during pre and/or post testing (i.e., were missing data on most measures), and two did not have a diagnosis of ADHD. (One had a diagnosis of Attention Processing Disorder. The other was apparently in the process of obtaining a diagnosis, but we never received confirmation that the diagnosis had been made.) This left a total sample size of 59 (30 in the motivation group and 29 in the study skills control group). Among those retained in the final sample, the motivation and study skills intervention groups were comparable on demographic measures at pretest (see Table 4.1), and a comparison of the participants who dropped out or were excluded to those who were included in the final sample indicated no difference between those groups either (see Table 4.2). A total of 25 participants returned for the follow up: 14 from the motivation group and 11 from the study skills group. A comparison of the full sample to those who returned for the follow-up also revealed no significant differences in demographic information (see Table 4.3). The motivation group and the study skills group performed comparably on all our outcome measures at pretest (see Table 4.4). However, on Spatial Persistence, the study skills control group did outperform the motivation group at baseline. This difference was approaching significance (p = 0.07), with the Bayes factor of 1.48 suggesting anecdotal evidence that the two groups may have been different from one another on this measure.

Table 4.1

Participant Demographic Information

	Motivation Group *M (SD)*	Study Skills Group *M (SD)*	*p*-value	*BF*
N	30	29		
Age	10 *(2.12)*	10.28 *(2.40)*	0.64	0.29
ADHD severity	18.77 *(5.59)*	18.69 *(6.01)*	0.96	0.27
Number of girls	8 (27.6%)	9 (31%)	0.71	0.31
Number medicated	17 (56.7%)	13 (44.8%)	0.43	0.43
Mother's education	16.07 *(2.28)*	15.37 *(2.54)*	0.28	0.44
Family income	$100,000+	$100,000+	0.74	0.01

Note. ADHD Severity as measured by parent report on the Behavior Rating Inventory of Executive Function, Second Edition (BRIEF2) working memory index at pretest. Mother's education is measured in years. Income mode is presented, as income was measured in bins. The *p*-values and Bayes factors are from *t*-tests for continuous variables and from chi-square tests for non-continuous variables. Bayes factors over 1 are considered evidence in favor of the alternative hypothesis. BF = Bayes factor. ADHD = Attention Deficit Hyperactivity Disorder.

Table 4.2

Demographic Information for Included and Excluded Participants

	Included Participants *M (SD)*	Excluded Participants *M (SD)*	*p*-value	*BF*
N	59	12		
Age	10.14 *(2.25)*	9.75 *(2.14)*	0.59	0.35
ADHD severity	18.73 *(5.75)*	18.82 *(2.71)*	0.96	0.32
Number of girls	17 (28.8%)	3 (25%)	0.79	0.24
Number medicated	30 (50.8%)	3 (25%)	0.11	0.74
Mother's education	15.73 *(2.42)*	14.82 *(5.38)*	0.37	0.44
Family income	$100,000+	$100,000+	0.39	0.03

Note. ADHD Severity as measured by parent report on the Behavior Rating Inventory of Executive Function, Second Edition (BRIEF2) working memory index at pretest. Mother's education is measured in years. Income mode is presented, as income was measured in bins. The *p*-values and Bayes factors are from *t*-tests for continuous variables and from chi-square tests for non-continuous variables. Bayes factors over 1 are considered evidence in favor of the alternative hypothesis. BF = Bayes factor. ADHD = Attention Deficit Hyperactivity Disorder.

Table 4.3
Demographic Information for the Full Sample and the Follow-Up Sample

	Full Sample *M (SD)*	Follow-Up Sample *M (SD)*	*p*-value	*BF*
N	59	25		
Age	10.14 *(2.25)*	9.52 *(2.33)*	0.26	0.43
ADHD severity	18.56 *(5.56)*	18.96 *(6.12)*	0.79	0.26
Number of girls	17 (28.8%)	9 (36%)	0.52	0.33
Number medicated	30 (50.8%)	11 (44%)	0.64	0.28
Mother's education	15.73 *(2.42)*	15.96 *(2.29)*	0.70	0.27
Family income	$100,000+	$100,000+	0.91	0.01

Note. ADHD Severity as measured by parent report on the Behavior Rating Inventory of Executive Function, Second Edition (BRIEF2) working memory index at pretest. Mother's education is measured in years. Income mode is presented, as income was measured in bins. The *p*-values and Bayes factors are from *t*-tests for continuous variables and from chi-square tests for non-continuous variables. Bayes factors over 1 are considered evidence in favor of the alternative hypothesis. BF = Bayes factor. ADHD = Attention Deficit Hyperactivity Disorder.

Table 4.4
Outcome Measures by Group at Pretest

	Motivation Group *M (SD)*	Study Skills Group *M (SD)*	*p*-value	*BF*
N	30	29		
Theories of Intelligence	2.52 *(0.85)*	2.59 *(0.75)*	0.75	0.28
Need for Cognition	2.74 *(0.68)*	2.90 *(0.63)*	0.37	0.38
Grit	3.13 *(0.69)*	2.96 *(0.59)*	0.33	0.01
Spatial Persistence	0.53 *(0.51)*	0.76 *(0.44)*	0.07	1.48
Verbal Persistence	0.37 *(0.49)*	0.55 *(0.51)*	0.15	0.84

Note. Scores for Spatial and Verbal Persistence reflect the proportion of participants who chose to persist. The *p*-values and Bayes factors are from *t*-tests for continuous variables and from chi-square tests for non-continuous variables. Bayes factors over 1 are considered evidence in favor of the alternative hypothesis. BF = Bayes factor.

A principal components analysis (varimax rotation) was used to explore the latent factor structure of the five outcome measure variables. The resulting factor loadings are listed in Table 4.5. The factor analysis yielded two factors, which accounted for 61.34% of the total variance. Variables loading on Factor 1 (34.81% of the total variance) represented the verbal and spatial persistence tasks. Variables loading on Factor 2 (26.53% of the total variance) represented Grit and Need for Cognition. Theories of Intelligence did not load onto either of the two factors. Based on this analysis, the following three variables were used as outcome measures: (1) Theories of Intelligence, (2) the average score of the two persistence measures (Persistence), and (3) a composite score of Grit and Need for Cognition ("Gritty NFC"). Gritty NFC was created by z-scoring the original variables and then averaging them together.

Table 4.5
Exploratory Rotated Factor Matrix

	Component	
Measure	1	2
Verbal Persistence	0.80	
Spatial Persistence	0.77	
Need for Cognition		0.78
Grit		0.42
Theories of Intelligence		

Note. All variables included in the factor analysis were from pretest. Extraction Method: Principal Axis Factoring. Rotation Method: Varimax with Kaiser Normalization.

Treatment condition failed to predict Theories of Intelligence at posttest ($F(2, 55) = 0.23$, $p = 0.63$, $\eta p^2 = 0.00$, $BF = 0.31$) or at follow up ($F(2, 21) = 1.13$, $p = 0.30$, $\eta p^2 = 0.05$, $BF =$

0.45). Similarly, treatment condition failed to predict Gritty NFC at posttest ($F(2, 55) = 0.58$, p = 0.45, $\eta p^2 = 0.01$, $BF = 0.29$) or at follow up ($F(2, 21) = 2.65$, $p = 0.12$, $\eta p^2 = 0.11$, $BF = 0.63$). Finally, treatment condition failed to predict persistence at posttest ($F(2, 54) = 0.89$, $p = 0.35$, ηp^2 = 0.02, $BF = 1.22$) or at follow up ($F(2, 22) = 0.02$, $p = 0.90$, $\eta p^2 = 0.00$, $BF = 0.38$). See tables 4.6 and 4.7 and figures 4.2–4.7.

Table 4.6
Descriptive Statistics by Group for the Outcome Variables at Pretest and Posttest for the full sample

	Motivation Group		Study Skills Group		Pre vs. Post	
	Pretest M *(SD)*	Posttest M *(SD)*	Pretest M *(SD)*	Posttest M *(SD)*	Cohen's *d*	*r*
N	30	30	29	29	59	59
Theories of Intelligence	2.52 *(0.85)*	2.54 *(1.05)*	2.59 *(0.75)*	2.70 *(0.69)*	0.08	0.54
Need for Cognition	2.74 *(0.68)*	2.74 *(0.80)*	2.90 *(0.63)*	2.85 *(0.61)*	0.10	0.69
Grit	3.13 *(0.69)*	3.18 *(0.65)*	2.96 *(0.59)*	3.19 *(0.66)*	0.40	0.71
Spatial Persistence	0.53 *(0.51)*	0.43 *(0.50)*	0.76 *(0.44)*	0.72 *(0.46)*	0.14	0.42
Verbal Persistence	0.37 *(0.49)*	0.37 *(0.49)*	0.55 *(0.51)*	0.55 *(0.51)*	0.00	0.66

Note. Scores for Spatial and Verbal Persistence reflect the proportion of participants who chose to persist. Effect size Cohen's $d = (M_2 - M_1) / SD_{pooled}$, where *M*'s were calculated as the change from pre to post within each group. Test–re-test reliability was calculated as a bivariate correlation between pre and posttest scores for the full sample.

Table 4.7

Descriptive Statistics by Group for the Outcome Variables at Pretest, Posttest, and Follow-Up for the Sample that Completed All Three Test Sessions

	Motivation Group			Study Skills Group			Pre vs. Follow-Up	
	Pretest M *(SD)*	Posttest M *(SD)*	Follow-Up M (SD)	Pretest M (SD)	Posttest M (SD)	Follow-Up M (SD)	Cohen's *d*	*r*
N	14	14	14	11	11	11	25	25
Theories of Intelligence	2.05 *(0.52)*	2.23 *(0.96)*	2.38 *(0.76)*	2.39 *(0.80)*	2.39 *(0.63)*	2.15 *(0.79)*	0.66	0.23
Need for Cognition	2.48 *(0.60)*	2.46 *(0.63)*	2.59 *(0.57)*	2.91 *(0.69)*	2.64 *(0.67)*	2.48 *(0.68)*	0.98	0.48
Grit	3.06 *(0.76)*	3.11 *(0.67)*	3.34 *(0.77)*	2.83 *(0.65)*	2.92 *(0.66)*	2.89 *(0.55)*	0.25	0.40
Spatial Persistence	0.57 *(0.51)*	0.46 *(0.52)*	0.71 *(0.47)*	0.64 *(0.51)*	0.55 *(0.52)*	0.64 *(0.51)*	0.24	0.32
Verbal Persistence	0.50 *(0.52)*	0.36 *(0.50)*	0.36 *(0.50)*	0.36 *(0.51)*	0.45 *(0.52)*	0.36 *(0.51)*	0.25	0.34

Note. Scores for Spatial and Verbal Persistence reflect the proportion of participants who chose to persist. Effect size Cohen's $d = (M_2 - M_1) / SD_{\text{pooled}}$, where *M*'s were calculated as the change from pre to follow-up within each group. Test–re-test reliability was calculated as a bivariate correlation between pre- and posttest scores for all participants who completed pretest and follow-up, regardless of group

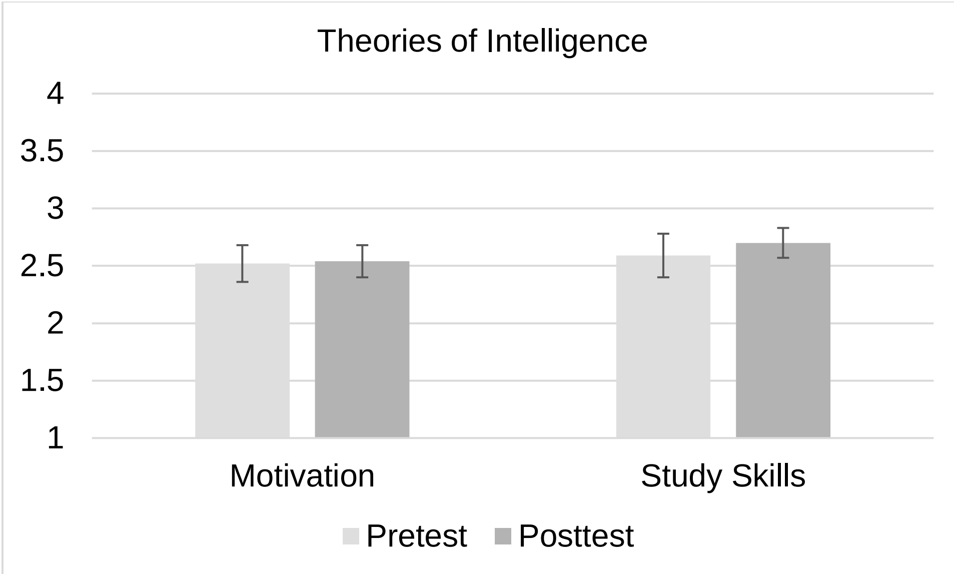


Figure 4.2. Theories of Intelligence scores at pretest and posttest by condition. A higher score indicates a greater endorsement of a growth mindset.

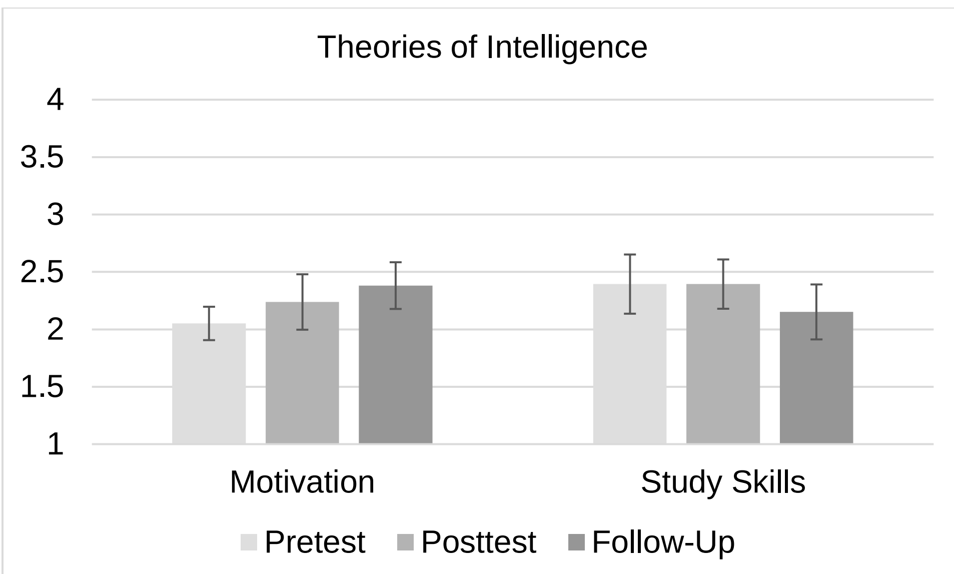


Figure 4.3. Theories of Intelligence scores at pretest, posttest, and follow up by condition. Only participants who completed the follow up were included. A higher score indicates a greater endorsement of a growth mindset.

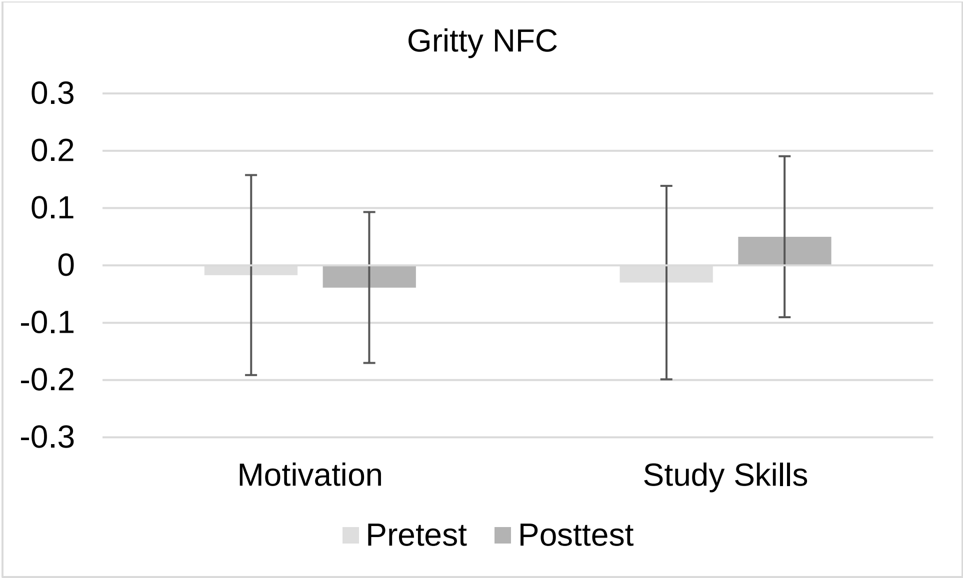


Figure 4.4. Gritty NFC scores at pretest and posttest by condition. This score represents a z-scored composite of Need for Cognition and Grit, where a higher score indicates a greater endorsement of Gritty NFC.

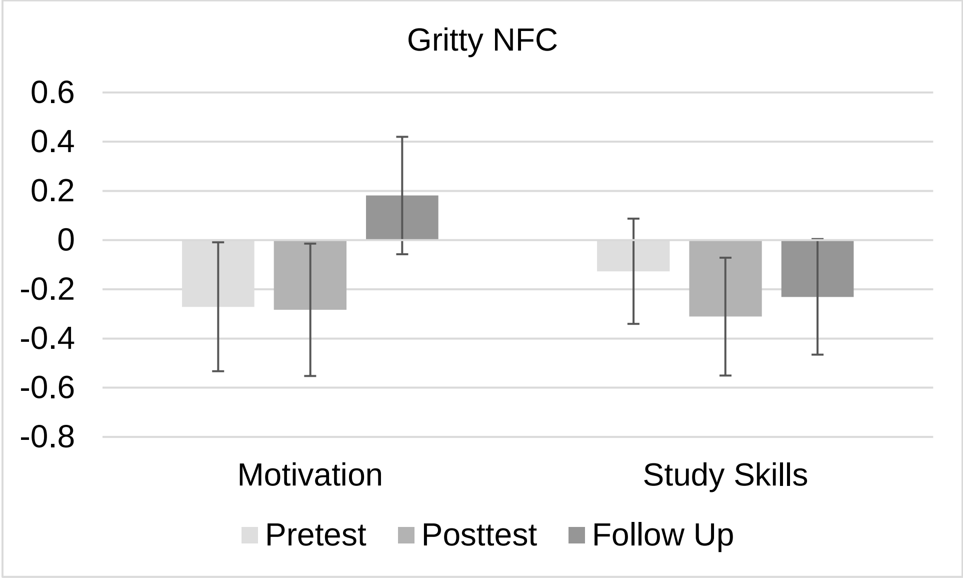


Figure 4.5. Gritty NFC scores at pretest, posttest, and follow up by condition. This score represents a z-scored composite of Need for Cognition and Grit, where a higher score indicates a greater endorsement of Gritty NFC. Only participants who completed the follow up were included.

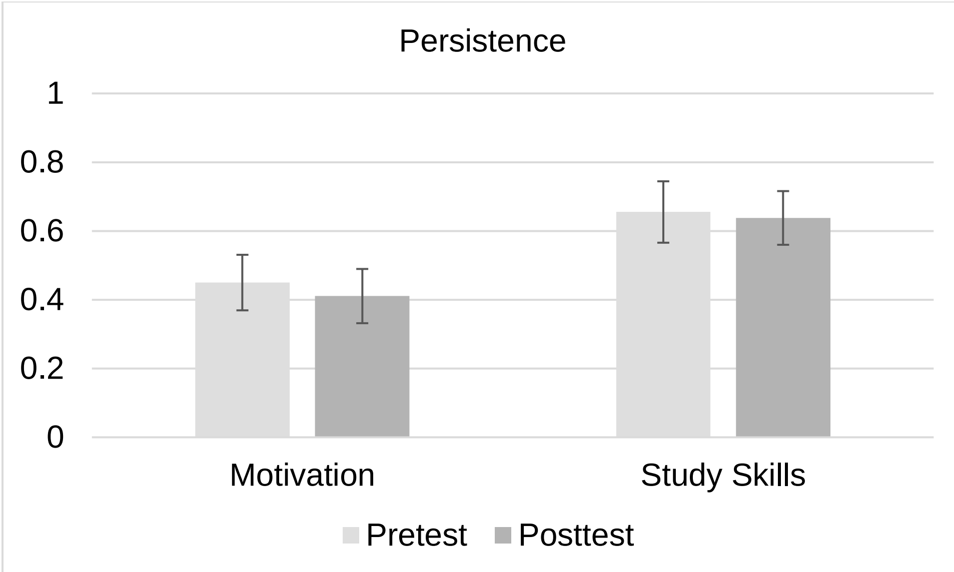


Figure 4.6. Persistence scores at pretest and posttest by condition. This score an average score of verbal and spatial persistence, where a higher score indicates a higher proportion of participants chose the more difficult problems.

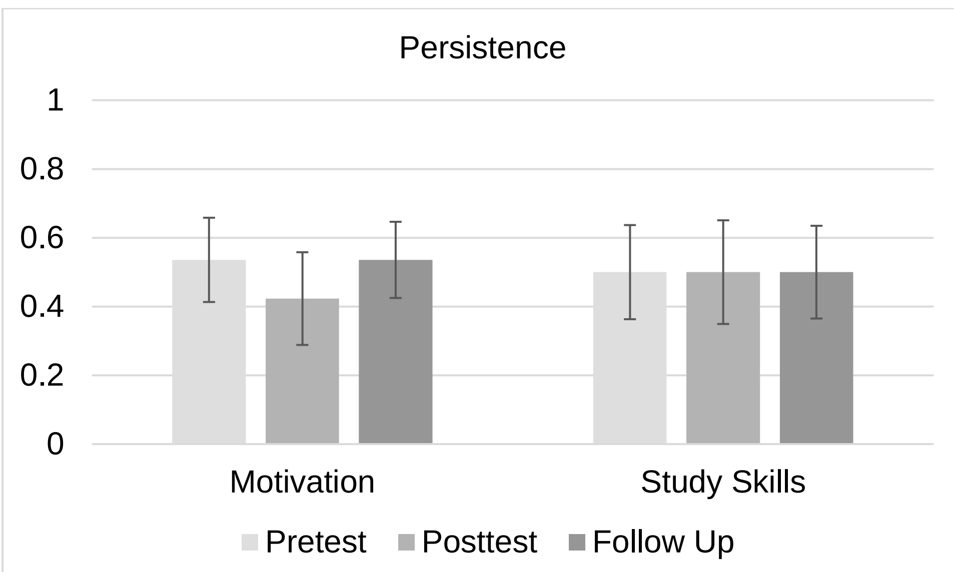


Figure 4.7. Persistence scores at pretest and posttest by condition. This score an average score of verbal and spatial persistence, where a higher score indicates a higher proportion of participants chose the more difficult problems. Only participants who completed the follow up were included.

Qualitative Analyses

A full detailing of the interview and focus group data is beyond the scope of this paper, as here we are primarily interested in understanding parents' perceptions of each interventions' success. As such, we discuss specifically the statements made by parents regarding their own parenting and the child's motivation and study skills.

Motivation Condition. First, we examined whether parents reported any changes in beliefs or whether they reported having taken up any of the practices we recommended during the parent orientation lesson in the motivation condition. The ideas that intelligence is malleable and the beneficial effects of a growth mindset were new to many parents. One parent commented that she learned that "*this idea that they're constantly learning as opposed to they're just smart or you know like this innate thing, that you know that stays static.*" Beyond teaching about mindset as a potentially useful concept, we explicitly taught parents to encourage a growth mindset by praising effort and incremental improvement as opposed to praising traits or successes (e.g., "I'm proud of you for working so hard" rather than "I'm proud of you for being so smart."). Several parents reported adjusting their language in this way. For example, one parent commented, "*…one of the pages from that initial handout like I keep in the kitchen just as a reminder of like don't praise this way but instead like adjust it to this language.*" Overall, the main theme that emerged regarding the parents was that they felt empowered to take up and continue to preach central messages from the intervention. They understood the concept that the ability to learn can be improved through effort, because the brain is able to continually make new connections. As one parent put it, "*It gave us something that we can continue talk about, like, you know, let's keep trying because your neurons are going to keep, you know, like, changing and that you know you shouldn't give up too quickly… So it's going to be nice to have that just kind of language that we can use.*"

Next we analyzed parents' responses to questions regarding their children's behaviors as they related to topics covered in the motivation intervention. Three major themes emerged from the data. First, we found that parents tended to report that their child had learned the concept of a growth mindset. One parent explained how her child learned to focus on the process of learning through support and effort as demonstrated by the use of the word "yet": "*We'll use the word 'yet.' Like, he'll throw it in there sometimes and it's like 'something something, well, not yet.' So maybe that, you know, I think that probably came from this…*"

The second theme revealed that children in the motivation condition tended to have increased self-awareness about their ADHD and their abilities. One parent described the impact of the intervention saying, "*[I'm] hopeful that just because, you know, there was at first a lot of the 'I'm not smart.' I don't get that anymore. It's like 'I learned, I learned something differently.'*" Another parent commented, "*And I think ultimately it helped him in his journey to maybe creatively understand himself better.*" These statements suggest that our efforts to teach children with ADHD about how their minds grow and change as they learn and about how children with ADHD can be highly creative may have successfully impacted some of our participants.

Thirdly, we found that children in the motivation condition seemed to have more self-confidence, to take more ownership of their learning, and were more willing to attempt difficult tasks. One parent described a change in her child's behavior following the intervention saying, "*Instead of like resistance, like 'no no I'm not going to do it,' he's more like 'ok I'll try. I'll try. You know, I don't, I can't guarantee, but I'll try my best.' So, that kind of positive feedback I can see from him, like, okay, he's more willing to face his, you know, weakness.*" This type of statement was a common thread among parents of children in the motivation condition, suggesting that our efforts to improve persistence in the face of difficulty may have successfully impacted our participants.

Study Skills Condition. Parents in the control group generally reported positive changes in their children's behavior, mostly related to strategies they learned in the intervention such as using a planner, spacing and interleaving study time, and note-taking strategies such as mind mapping. Both child and parent participants in the control condition spent time learning about and discussing priorities. Children were asked to explicitly write out their top priorities in life, and this activity seemed to profoundly affect some of the families. As one mother explained, "*he will have these moments, where recently, he's been saying, 'I really love my family. You think I love video games more, but I really love my family.' So I think getting him to think in those kinds of terms, really didn't happen before that lesson. So I think that was probably pretty prevalent during our time here.*" Quotes like these demonstrate that even the control condition had the potential to significantly impact the lives of the families in our intervention.

Disconfirming Evidence. In some cases, across conditions, parents did provide disconfirming evidence, suggesting that individual families experienced the intervention differently. Some parents remarked that they didn't remember what was discussed in the parent session and other said that, while their child had improved on certain behaviors, there had been many other changes in their child's life during the same period of time, making it difficult to accurately attribute the source of the change. For the most part, however, parents described a positive experience and improved patterns of thought and behavior for themselves and for their children.

Discussion

This study was a feasibility study that aimed to increase motivation and persistence among children with ADHD. Our qualitative data suggests that the families in our intervention group benefited from participating. There were reports suggesting that children gained increased awareness of their own strengths and weaknesses and developed better confidence and took greater ownership of their school work. It seems, though, that our intervention did not have an impact of the constructs we measured. Quantitatively testing whether the intervention improved motivation and persistence proved to be a difficult task, as this study suffered from many measurement issues.

One of our primary motivation outcome measures was the Theories of Intelligence questionnaire. We explicitly taught the treatment group and their parents about growth mindset, yet we did not find that the treatment group significantly outperformed the control group at posttest. The Theories of Intelligence questionnaire may not have been appropriate for our age range. The author recommends this scale for ages 10 and older (Dweck, 2010b), yet our sample included children ages seven through 14. Some of the younger children in our sample even expressed confusion regarding the meaning of the word “intelligence.” Thus, results from this measure should be interpreted with caution. Nonetheless, among the participants who completed pretest, posttest, and follow up, we observed a positive trend suggesting that mindset might have changed with time in the treatment group (see Fig. 4.2), however, these findings failed to reach significance. Our Need for Cognition and our Grit measures suffered from similar issues. Both were designed for adults, not children (Cacioppo et al., 1984; Duckworth & Quinn, 2009). Additionally, as the testing sessions were quite long for children, especially those with ADHD, efforts were made to minimize testing time. A subset of items was selected from the complete Need for Cognition scale, which may have compromised its reliability. Moreover, the internal reliabilities (Cronbach’s α) for these three scales in our sample were all less than 0.68, which is well below the recommended 0.80 for basic research and 0.90 for applied research (Nunnally, 1978).

We measured persistence with two tasks: a block puzzle task and a verbal reasoning task. Both of these tasks measured persistence as whether or not the child chose to continue with a harder task rather than with an easier task. A binary outcome is not ideal for measuring improvement following a brief intervention. If a child chose the easy option at pretest (i.e., was "non-persistent"), he or she could either stay the same or go higher (demonstrate "persistence"). If a child chose hard at pretest, however, they can only go down or stay the same. Thus, participants did not have an equal opportunity to improve on these measures.

In addition to that issue, the relative ease and difficulty of the items in both tasks was not appropriate for all children, especially given our wide age range. If the easy task was too difficult for a participant, then the appropriate choice would be the easier option, not the harder one. In this scenario, the task does not measure persistence. We found this to be an issue for both the verbal and spatial persistence tasks, especially for our younger participants. The developmental gap between the youngest and oldest students was quite pronounced, and some items seemed unreasonably hard for the younger students yet trivial for the older students.

Unfortunately, our persistence tasks also failed to align with what was taught in the lessons. Drawing from Utility Value Theory, which suggests that one will persist when tasks are both useful and of value to that individual (Wigfield et al., 2015), we encouraged participants in the motivation group to keep persisting on tasks that were important to them. They were told that, although certain tasks in life are difficult, they could improve with practice and they should persist even when things are challenging, in order to achieve their goals. Selecting the harder task at post-test did not necessarily meet those specifications, as it was not related to something important to them.

The wide age range of participants was a significant challenge for implementing the intervention itself. As it is difficult to recruit from this specific population, our aim was to be as inclusive as possible, however, our participants were ages seven through 14, representing very different developmental stages. At times this was actually an advantage, as the older children were able to support the learning of the younger children. In scenarios when this occurred, the group demonstrated higher engagement with the lessons, and the older children were likely better able to learn after having taken on a teaching role (Cohen, Kulik, & Kulick, 1982). On the other hand, sometimes the content was too juvenile or boring for older children and too challenging for younger children. The metacognitive nature of the discussion may have been beyond younger children's comprehension ability (Nicholls & Miller, 1984). In our experience, the concepts presented in the lessons seemed easier to grasp for children who were at least 10 years old.

In addition to our sample having a wide age range, we also had children that were much younger than those who participated in the studies that informed our study. Those primarily targeted typically developing older children, adolescents, and emerging adults (Aronson et al., 2002, Blackwell et al., 2007, Good et al., 2003; Yeager et al., 2016), whereas our intervention was developed for younger children with ADHD – both a different age group and a different population. It may have been helpful to first test out our intervention with either typically developing younger children or with an older sample of individuals with ADHD, rather than making both changes in one step.

Despite the challenges, our qualitative data suggests that the parent session was quite beneficial. This session armed parents with information that enabled them to implement the key concepts from our intervention at home. We only had four brief sessions with the children, but a parent who can reinforce concepts related to mindset and persistence daily has a much greater potential to impact their children's lives. Thus, this was a key component, and future studies might consider placing greater emphasis on educating parents directly.

Conclusion

Children with ADHD tend to endorse a fixed mindset and to demonstrate low self-efficacy, reduced persistence in response to challenge, and academic underachievement as compared with typically developing children. Because individuals with ADHD are theorized to have an underlying motivational impairment (Dunn & Shapiro, 1999; Sonuga-Barke, 2002), we developed an intervention to test whether a set of small-group lessons could influence the mindset and persistence in children with ADHD as compared to a control intervention. Our quantitative analyses failed to reveal any significant improvements in the intervention group compared to the control group, however, the study suffered from significant measurement issues, making that data difficult to appropriately interpret. Our qualitative data, while not conclusive, was more illuminating. We found that parents learned about growth mindset and other concepts covered in the intervention, and that they were able to use techniques taught during their session. We also found that children in the intervention group tended to have increased self-awareness, a more positive outlook, and took more ownership of their school work, which we did not find evidence of in the control group. Future research should emphasize measurement and be very thoughtful about the developmental appropriateness of intervention content. Overall, our promising qualitative findings suggest that continuing this line of research is a worthy goal.

References

Aronson, J., Fried, C. B., & Good, C. (2002). Reducing the effects of stereotype threat on African American college students by shaping theories of intelligence. *Journal of Experimental Social Psychology, 38*(2), 113–125. https://doi.org/10.1006/jesp.2001.1491

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65–94. https://doi.org/10.1037/0033-2909.121.1.65

Barkley, R. A., Fischer, M., Smallish, L., & Fletcher, K. (2002). The persistence of attention-deficit/hyperactivity disorder into young adulthood as a function of reporting source and definition of disorder. *Journal of Abnormal Psychology*, *111*(2), 279–289. https://doi.org/10.1037/0021-843X.111.2.279

Bjork, E. L., & Bjork, R. (2011). Making things hard on yourself, but in a good way: creating desirable difficulties to enhance learning. In *Psychology in the real world: Essays illustrating fundamental contributions to society* (pp. 56–64).

Blackwell, L. S., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development*, *78*(1), 246–263.

Cacioppo, J. T., Petty, R. E., & Kao, C. F. (1984). The efficient assessment of need for cognition. *Journal of Personality Assessment*, *48*(3), 306–307. https://doi.org/10.21074/kjlcap.2007.8.1.127

Carlson, C. L., Booth, J. E., Shin, M., & Canu, W. H. (2002). Parent-, teacher-, and self-rated motivational styles in ADHD subtypes. *Juornal of Learning Disabilities*, *35*(2), 104–113.

ClassDojo. (2016). Growth mindset for students - episode 1/5. Retrieved from https://www.youtube.com/watch?v=2zrtHt3bBmQ

Cohen, P. A., Kulik, J. A., & Kulick, C.-L. C. (1982). Educational outcomes of tutoring :A meta-analysis of findings. *American Educational Research Journal*, *19*(2), 237–248.

Cury, F., Elliot, A. J., Da Fonseca, D., & Moller, A. C. (2006). The social-cognitive model of achievement motivation and the 2 × 2 achievement goal framework. *Journal of Personality and Social Psychology*, *90*(4), 666–679. https://doi.org/10.1037/0022-3514.90.4.666

DSM-IV Diagnostic and Statistical Manual of Mental Disorder. (1994). *American Psychiatric Organization*. https://doi.org/10.1073/pnas.0703993104

Duckworth, A. L., & Quinn, P. D. (2009). Development and validation of the short grit scale (Grit-S). *Journal of Personality Assessment*, *91*(2), 166–174. https://doi.org/10.1080/00223890802634290

Dunn, P. B., & Shapiro, S. K. (1999). Gender Differences in the achievement goal orientations of ADHD Children. *Cognitive Therapy and Research*, *23*(3), 327–344.

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist*, *41*(10), 1040–1048. https://doi.org/10.1037/0003-066X.41.10.1040

Dweck, C. S. (2010a). Carol Dweck: The effect of praise on mindsets.

Dweck, C. S. (2010b). *Mindset: The new psychology of success*. New York, New York, USA: Ballantine Books.

Dweck, C. S., & Leggett, E. L. (1988). A social cognitive approach to motivation and personality. *Psychological Review*, *95*(2), 256–273. https://doi.org/10.1037/0033-295X.95.2.256

Faraone, S. V., Biederman, J., & Mick, E. (2005). The age-dependent decline of attention deficit hyperactivity disorder: a meta-analysis of follow-up studies. *Psychological Medicine,* *36*(02), 159. https://doi.org/10.1017/S003329170500471X

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2005). *BRIEF-2: Behavior Rating Inventory of Executive Function: Professional Manual*. Psychological Assessment Resources.

Good, C., Aronson, J., & Inzlicht, M. (2003). Improving adolescents' standardized test performance: An intervention to reduce the effects of stereotype threat. *Journal of Applied Developmental Psychology*, *24*(6), 645–662. https://doi.org/10.1016/j.appdev.2003.09.002

Haimovitz, K., Wormington, S. V., & Corpus, J. H. (2011). Dangerous mindsets: How beliefs about intelligence predict motivational change. *Learning and Individual Differences*, *21*(6), 747–752. https://doi.org/10.1016/j.lindif.2011.09.002

Jacobson, L. A., Pritchard, A. E., Koriakin, T. A., Jones, K. E., & Mahone, E. M. (2016). Initial Examination of the BRIEF2 in Clinically Referred Children With and Without ADHD Symptoms. *Journal of Attention Disorders*. https://doi.org/10.1177/1087054716663632

Landau, M. J., Oyserman, D., Keefer, L. A., & Smith, G. C. (2014). The college journey and academic engagement: how metaphor use enhances identity-based motivation. *Journal of Personality and Social Psychology*, *106*(5), 679–698. https://doi.org/10.1037/a0036414

LitmusHeroes. (2014). Rocks, pebbles, and sand story. Retrieved from https://www.youtube.com/watch?v=v5ZvL4as2y0

NCES. (2016). NCES fast facts.

Nicholls, J. G., & Miller, A. T. (1984). Reasoning about the ability of self and others: A developmental study. *Child Developement*, *55*(6), 1990–1999.

Nunnally, J. (1978). *Psychometric theory* (2nd ed.).

Oyserman, D. (2014). Identity-based motivation: Core processes and intervention examples.

Advances in Motivation and Achievement, *18*, 215–245. https://doi.org/10.1108/S0749-742320140000018006

Pastor, P. N., & Reuben, C. a. (2002). Attention deficit disorder and learning disability: United States, 1997-98. *Vital and Health Statistics. Series 10, Data from the National Health Survey*, 1–12.

Pintrich, P. R. (2000). Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. *Journal of Educational Psychology*, *92*(3), 544–555.

Pintrich, P. R., & de Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*(1), 33–40. https://doi.org/10.1037/0022-0663.82.1.33

Schwartz, D. L., Cheng, K. M., Salehi, S., & Wieman, C. (2016). The half empty question for socio-cognitive interventions. *Journal of Educational Psychology*, *108*(3), 397–404. https://doi.org/10.1037/edu0000122

Sonuga-Barke, E. J. S. (2002). Psychological heterogeneity in AD/HD — a dual pathway model of behaviour and cognition. *Behavioral Brain Research*, *130*, 29–36.

Tabassam, W., & Grainger, J. (2002). Self-concept, attributional style and self-efficacy beliefs of students with learning disabilities with and without attention deficit hyperactivity disorder. *Learning Disabilities Research and Practice*, *25*(2), 141–151. Retrieved from https://www.youtube.com/watch?v=TTXrV0_3UjY

Thomas, A. J., & Sarnecka, B. W. (2015). Exploring the relation between people's theories of intelligence and beliefs about brain development. *Frontiers in Psychology*, *6*(July), 1–12. https://doi.org/10.3389/fpsyg.2015.00921

VERBISoftware. (2016). MAXQDA Analytics Pro [Computer Programme]. Berlin, Germany:

VERBI.

Wigfield, A., Eccles, J. S., Fredricks, J. A., Simpkins, S., Roeser, R. W., & Schiefele, U. (2015). Development of achievement motivation and engagement. *Handbook of Child Psychology and Developmental Science, Volume 3, Socioemotional Processes, 7th Edition*, *3*, 1–44. https://doi.org/10.1002/9781118963418.childpsy316

Yeager, D. S., Walton, G. M., Brady, S. T., Akcinar, E. N., Paunesku, D., Keane, L., … Rose, H. (2016). Teaching a lay theory before college narrows achievement gaps at scale. *PNAS*, *113*(24), E3341–E3348. https://doi.org/10.1073/pnas.1524360113

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology*, *25*, 82–91. https://doi.org/10.1006/ceps.1999.1016

Zimmerman, B. J., Bandura, A., & Martinez-Pons, M. (1992). Self-motivation for academic attainment: The role of self-efficacy beliefs and personal goal setting. *American Educational Research Journal*, *29*(3), 663–676. https://doi.org/10.3102/00028312029003663

CHAPTER 5

Concluding Remarks and Future Directions

Attention Deficit Hyperactivity Disorder (ADHD) affects a significant proportion of the population (Visser et al., 2014) and has the highest co-morbidity rate in psychopathology (Maniadaki & Kakouros, 2017). It is important to improve our understanding of ADHD in order to address not only the symptoms but also the consequences of ADHD, such as students with ADHD having high rates of academic underperformance compared to their peers (DuPaul & Stoner, 2014). This dissertation examined co-morbidity in ADHD and potential treatment options by drawing from the Dual Pathway model of ADHD, which suggests that major underlying contributors to ADHD are executive dysfunction and delay aversion (see Figure 1.1). In this chapter I review the findings from each of the studies, discuss major themes and provide suggestions for future research that emerged from them, and propose a new social–cognitive model of ADHD.

Summary and Implications of Findings

Study 1. The Relations among ADHD Symptoms, Reading Ability, and Executive Functioning.

In this study, I drew from the executive dysfunction branch of the Dual Pathway model to examine the nature of the association between ADHD symptoms and reading ability. I chose to study reading ability as a window into co-morbidity in ADHD, as Reading Disability (RD) is present in 18.9–44% of individuals with ADHD (Carroll, Maughan, Goodman, & Meltzer, 2005; Pastor & Reuben, 2002). I hypothesized that the association between ADHD symptoms and reading comprehension would be stronger than that between ADHD symptoms and word reading. I further hypothesized that executive functioning (EF) would partially mediate the relation between

ADHD symptoms and reading comprehension. This hypothesis was based on the idea that executive dysfunction, which plays a role in ADHD, also plays a role in reading (reading comprehension in particular), and that this shared deficit in EF might partially explain why ADHD and RD are so frequently co-diagnosed. The results indicated that the association between ADHD symptoms and reading comprehension, while small, was five times larger than that between ADHD symptoms and word reading, and that EF partially mediated both associations.

These findings lend support to the theory that executive dysfunction may be a key factor in understanding why ADHD and RD are co-diagnosed at such a high rate. Although causal claims cannot be substantiated due to the correlational nature of this study, it is possible that low EF may be one of the causes contributing to both ADHD symptoms and reading problems. There was a direct effect between ADHD symptoms and reading ability, suggesting that the two are, in fact, related. Indeed, longitudinal work has found that attention problems predict reading achievement, even after controlling for previous reading achievement (Rabiner et al., 2000).

We found that EF partially mediated the relation between reading and ADHD symptoms. The effect was very small, which is consistent with theories suggesting that ADHD and related developmental disorders are heterogeneous in nature and etiology (e.g., Maniadaki & Kakouros, 2017; Sonuga-Barke, 2002). A partial mediation indicates that the non-mediated association between ADHD symptoms and reading ability is explained by other factors not measured in this study, such as motivation (Lee & Zentall, 2017). In a study by Pennington, Groisser, & Welsh (1993), children with ADHD, RD, co-morbid ADHD and RD, and typically developing children were assessed on measures of phonological processing and EF. The authors found that children with ADHD had poor EF without poor phonological processing whereas children with RD or co-morbid RD and ADHD demonstrated poor phonological processing without EF deficits, suggesting that ADHD symptoms were secondary to RD. The authors offer the following hypothetical account to illustrate how ADHD symptoms might develop from a primary impairment in reading:

> The child has a congenital mild language disability, with noticeable problems in aspects of early language development, such as articulation and productive syntax (Scarborough, 1990)… The child's early language difficulties interact with his environment, which, although adequate, does not provide consistent structure and support. The child begins to show ADHD symptoms, such as not listening to adults and short attention span, possibly as early as 3–4 years old. In kindergarten, demands begin for prereading skills, such as learning letter names and letter–sound correspondences. As reading demands grow over the years, the child experiences increasing frustration, leading to more ADHD symptoms, including fidgeting, not following instructions, and speaking out of turn. His problems in both reading and behavior become evident to the school, and he is placed in special classes. His mother, pressed by the demands of being a single parent, does not recognize the need for intervention or does not have the time or money for therapy. Therefore, the child does not get the therapeutic services that he needs. The child begins to see himself as a troublemaker and begins to seek out other children with antisocial tendencies. Increasingly, his behavior brings him into conflict with rules and expectations. By the age of 9, he has the full-blown behavioral symptomatology of ADHD, according to both parent report and professional diagnosis. In cognitive testing, he demonstrates impaired phonological processing skills, but he performs well on tests of executive function skills, because his ADHD symptoms are not caused by a primary executive function deficit.

This account illustrates that the relation between ADHD symptoms and reading may, in many cases, have little to do with an underlying EF deficit and more to do with poor language and literacy skills interacting with the child's environment to produce ADHD symptoms. This would explain why the EF mediation between ADHD symptoms and reading was so small in our study. However, it is important to point out that the internal reliability of the EF measure in our sample was low. It is also possible that, with better measurement, this association might have been stronger.

Regardless of the role of EF in the association between ADHD symptoms and reading comprehension, the finding that the two have a strong association has implications for educational practice. Children with ADHD or attention problems should be screened for component reading skills. This would help teachers more effectively improve their students' academic achievement, which is particularly important for children with ADHD who typically underperform academically (DuPaul & Stoner, 2014; Pastor & Reuben, 2002). Practitioners may also consider cognitive training as a potential support for children with reading and attention problems (e.g., Loosli et al., 2011; Jones et al., 2018), however, the expectation should not be that cognitive training will be enough on its own. It is clear that EF not does explain the full range of variance in developmental disorders, so attention should also be placed upon other domains, such as motivation (e.g., study 3), with ideal interventions potentially including multiple domains such as cognitive training paired with approaches that target motivational issues.

Study 2. Exploring N-Back Cognitive Training for Children with ADHD.

Drawing again from the executive dysfunction branch of the Dual Pathway model, study 2 attempted to improve EF directly in children with ADHD via n-back cognitive training. We found that the experimental group improved on measures of working memory and inhibition, with some suggestion of improvements in related, parent-reported ADHD symptoms that were observed several months after training completion. These effects were correlated with the magnitude of training gains, suggesting that those who were more fully engaged with the training task were better able to benefit from it. The effect sizes were small, but overall the results suggest that n-back training may be useful in addressing some of the cognitive and behavioral issues associated with ADHD, as predicted based upon the executive dysfunction theory.

The results from this study lend partial support for the Executive Function Theory embedded within the Dual Pathway model. The theory suggests that, in some but not all instances of ADHD, there is an underlying dysfunction in EF. If that is the case, then training EF ought to improve ADHD symptoms. We found some suggestion of improvements in parent-reported ADHD symptoms, but the finding failed to reach significance at the 0.05 level ($p = 0.07$). However, the Bayes factor was 1.11, indicating some evidence in favor of the alternative hypothesis. Replications with a larger sample in which children who have ADHD with a confirmed EF deficit might find a larger and more pronounced effect.

Practically, the results from this study suggest that parents and professionals should consider cognitive training as a potential tool to support children with ADHD, as our participants did make statistically significant improvements on measures of working memory and inhibitory control. While studies and even meta-analyses offer conflicting conclusions regarding the efficacy of cognitive training (Au, Buschkuehl, Duncan, & Jaeggi, 2016; Au et al., 2015; Melby-Lervåg & Hulme, 2016), we have highlighted the importance of attending to individual differences in cognitive training work (Katz, Jones, Shah, Buschkuehl, & Jaeggi, 2016). Considering that EF deficits are not present in all individuals with ADHD (Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005), cognitive training interventions targeting ADHD symptoms should be recommended only for those individuals who do have EF deficits.

In addition to considering individual differences in etiological profiles, it is important to consider motivation and persistence. We found that transfer from training was correlated with training gains. This replicates the finding from Jaeggi and colleagues (2011), which showed that individuals who performed well on the n-back training task demonstrated far transfer, whereas those who performed poorly on the same training task did not. The authors explored participants' ratings of how much they enjoyed the task versus how difficult the task was in order to find potential explanations for why participants might differ in their training performance. They found that both high and low performing children enjoyed the task, but that lower-performing children rated the task as more difficult. The n-back task automatically adjusts difficulty level based on performance, so the two groups should have both been training at an appropriately difficult level. Based on this, Jaeggi and colleagues (2011) argued that low performing participants may have been those with lower frustration tolerance. Indeed, children with ADHD tend to struggle with overcoming frustration (Seymour, Macatee, & Chronis-Tuscano, 2016). As such, persisting on the n-back task may be particularly challenging for them.

These findings, in conjunction with the Dual Pathway model's indication of motivational deficits among individuals with ADHD, suggests that there might be motivational barriers to children successfully improving on the n-back task. Perhaps with increased motivation, children with ADHD could persist through this challenging training program and progress more drastically, which would correlate with greater gains on transfer measures such as working memory, inhibitory control, and ADHD symptoms (Jaeggi et al., 2011; Jones et al., 2018). Thus, with the intention of improving persistence in children with ADHD, we developed and tested a motivation intervention (study 3).

Study 3. Fostering Persistence among Children with ADHD: Can a Motivational Intervention Help?

Drawing from the delay aversion branch of the Dual Pathway model, we developed an intervention aimed at improving persistence in children with ADHD by addressing concepts and strategies drawn from motivation theories. Qualitative data from the study suggested that the families in in the intervention group benefited from participating. There were reports suggesting that children gained increased awareness of their own strengths and weaknesses, developed better confidence, and took greater ownership of their school work. It seems, though, that our intervention did not have a measurable impact of the constructs we assessed. Quantitatively testing whether the intervention improved motivation and persistence proved to be a difficult task, as this study suffered from many measurement problems, and there were issues with providing developmentally appropriate content to our large age range. Despite these challenges, our data suggest that the parent session was quite beneficial. This session armed parents with information that enabled them to implement the key concepts from our intervention at home. We only had four brief sessions with the children, but a parent who can reinforce concepts related to mindset and persistence daily has a much greater potential to impact their children's lives.

In order for this study to support of the Dual Pathway model, we would have needed to provide evidence that improving motivation among children with ADHD also improved their ADHD symptoms. Unfortunately, we were not able to quantitatively demonstrate improvements in motivation (likely at least in part to measurement issues), and we were also not able to quantitatively demonstrate improvements in persistence (our only measure of ADHD symptoms, also suffering from significant measurement issues). Thus, future work attempting to experimentally demonstrate a causal association between motivation and ADHD symptoms is needed. Such work will require the employment of more thoughtful measurement and would benefit from more sessions with the child, as four 1-hour session may not be enough time to make a significant impact.

Another route, rather than or in addition to more sessions with the children, would be to focus on lessons for the parents themselves. Delay Aversion theory stresses the importance of parenting, predicting that ADHD may be the outcome of genetically susceptible child interacting with their environment, with parental practices playing a moderating role (Sonuga-Barke, 2005). Sonuga-Barke suggests that some children are genetically predisposed to have a negative reaction to waiting and delay. These "delay averse" children tend to prefer small and immediate rewards over bigger and delayed ones. When parents hold standards that are too high for their children, do not forgive failures to wait, and/or do not follow through on threats or promises, they are more likely to construct an environment in which ADHD symptoms can emerge. In such a context, children are more likely to have unpleasant experiences of failure and disappointment and to mistrust future events, resulting in a learned behavior of escaping situations that require waiting or delay. Such learned behaviors present as hyperactivity, impulsivity, and inattention (see Chapter 1 for a more in-depth discussion).

Based on this theory and on the findings from study 3, interventions addressing parenting practices early and often in order to prevent and manage ADHD symptoms in predisposed children may be particularly beneficial. Indeed, positive parenting predicts fewer conduct problems among children with ADHD (Chronis et al., 2007), and behavioral parent training has been well-established as an evidence-based practice (Knight, Rooney, & Chronis-Tuscano, 2008). In our qualitative analysis, we found that addressing the parents may have a greater impact than intervening directly with the children who have ADHD, as parents were more likely to report having learned specific concepts and strategies taught during our lessons. Parents are with their children every day, and are thus better positioned to impact their lives, compared to researchers or clinicians who have limited time with them.

General Discussion: Heterogeneity in ADHD and Personalization of Treatment

Behavioral interventions such as those reported in this dissertation are typically between-subjects randomized controlled trials (RCTs), in which the researchers report average changes in a treatment group compared to average changes in a control group. This is considered the gold standard for evaluating whether a treatment is successful or not (Lüscher, 2013). However, such an approach assumes that the patients or participants are homogeneous and that the treatment effect will be homogenous. Thus, while between-subject RCTs can describe average between-subject treatment responses, they are frequently unable to answer the more clinically relevant question of how a given individual will respond to that specific treatment or intervention. Ultimately, we hope to use the knowledge gleaned from an RCT to predict a specific patient's response to treatment over time, which means we are actually interested in a within-subject difference (Davidson, Peacock, Kronish, & Edmondson, 2014). Even when a treatment demonstrates statistically-significant between-subject improvements, it is quite possible that some individuals within that treatment group failed to respond or even responded negatively to treatment. In practice, we have little or no way of telling whether a patient would have the expected average response to treatment or a null or negative response. For example, while we found an overall improvement in working memory following cognitive training in study 2, there are individuals in that group who performed worse at posttest than at pretest. Thus, in practice, it is potentially misleading to label an intervention as successful if it is only successful on average.

One solution to this problem comes from an approach called personalized medicine, developed for drug trials when advances in genetics made personalization potentially feasible. While the goal of traditional RCTs is to minimize the effect of individual differences between groups, this approach first creates subgroups of individuals according to etiological similarities and then randomizes them according to condition (Davidson et al., 2014). Such approaches focusing on individual differences, as advocated in Katz, Jones, Shah, Buschkuehl, & Jaeggi (2015), would help in advancing our ability to develop and test interventions. This is critical for ADHD, as it is an etiologically and neuropsychologically heterogeneous disorder, with individuals affected at varying degree and in various domains (Maniadaki & Kakouros, 2017).

As the studies in this dissertation can all be described were preliminary, pilot, or feasibility studies, individual differences in ADHD symptomatology were not examined due to sample size limitations. Thus, we were unable to follow the personalized medicine approach of subgrouping participants according to etiological similarities. In study 1, we found that ADHD symptoms were related to reading ability and that this association was partially mediated by EF. We know, however, that EF is only a deficit in approximately 50% of individuals with ADHD (Nigg et al., 2005). Larger studies allowing for subgrouping of children diagnosed with ADHD according to the presence or absence of an EF deficit would be more insightful in understanding these associations.

This issue was also present in Study 2. We attempted to improve EF in children with ADHD, however, we did not restrict our recruitment to children with ADHD who had a confirmed EF deficit or include a large enough group of participants to allow for subgrouping of participants according to the presence or absence of EF deficits. If we were able to do so, we might expect much larger effects from our intervention. In Study 3 we attempted to improve persistence by teaching children various concepts and strategies related to motivation. Just over half of children with ADHD demonstrate delay aversion (Sonuga-Barke, Dalen, & Remington, 2003). If we were able to find those specific children with ADHD who are delay averse, or include a large enough sample to allow for subgrouping of participants according to the presence or absence of delay aversion, then perhaps this intervention might have been more successful as well.

The Social–Cognitive Model of ADHD

The Dual Pathway Model of ADHD that was used to develop this work, identifies executive dysfunction and delay aversion as key contributors to ADHD symptomatology. However, this model fails to capture the full complexity of ADHD that has been observed in the literature and in this dissertation work. I therefore propose a social–cognitive model of ADHD that takes into account the child's proximal environment (which includes parenting practices and beliefs and school) and distal environment (which include policies and societal standards) in addition to the individual-level motivational and cognitive factors addressed by the Dual Pathway Model.

Consistent with the bioecological model of human development (Bronfenbrenner & Morris, 2007), this model considers distal factors such as national policies and cultural priorities that shape the educational experience for all students. ADHD is diagnosed when symptoms of ADHD (which are present in all people at varying degree) are significant enough to cause what is considered to be a "clinical impairment" (American Psychiatric Association, 2014). What is tolerated as "normal behavior" versus "clinical impairment" is entirely dependent on context. For example, dyslexia does not exist in an illiterate society. By the same logic, a setting in which children are faced with high expectations of academic performance, focused attention, and compliance with complex rules is more likely to be a place where children's ADHD symptoms can cause a clinical impairment, as compared to an alternative setting in which hyperactive and inattentive tendencies might go unnoticed or be less likely to be considered inappropriate. Policies such as No Child Left Behind or Every Student Succeeds Act, for example, which require high-stakes testing, influence the child's more proximal school environment. In this example, more testing likely results in increased pressure in school to succeed, which requires high levels of motivation, and high levels of executive functioning, both of which are child-level factors that may be compromised in children with ADHD.

As previously discussed, Sonuga-Barke (2005) emphasized the importance of parents by theorizing that when parents hold standards that are too high for their children, do not forgive failures to wait, and/or do not follow through on threats or promises, they are more likely to construct an environment in which ADHD symptoms can emerge. Children have unpleasant experiences of failure and disappointment and learn to mistrust future events. This results in a learned behavior of escaping situations that require waiting or delay, with this escape presenting as hyperactivity, impulsivity, and inattention. Concerning motivation, the literature suggests that certain parenting practices, such as praising effort rather than talent, result in a child's growth mindset (Haimovitz & Dweck, 2017). We found in our research (study 3) that parents of children with ADHD were generally not aware of such parenting practices and may have been inadvertently supporting the development of a fixed mindset, potentially leading to maladaptive motivational patterns related to the belief that cognition is not malleable. Such beliefs may result in a lack of effort or engagement in activities that encourage cognitive enhancement (e.g., any challenging academic task such as reading comprehension). This is particularly important for children with ADHD to may already have challenges relating to their cognitive abilities, such as executive dysfunction. This is where the spiral turns back upon itself (see Figure 5.1).

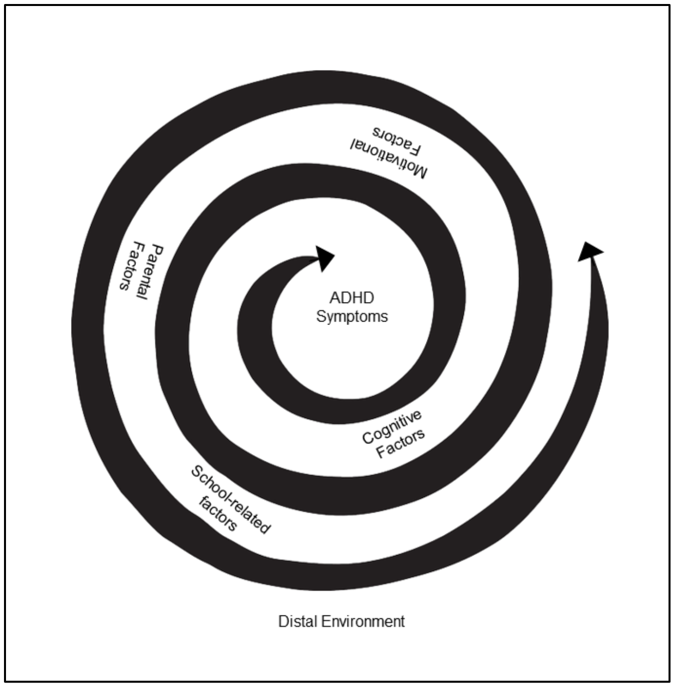


Figure 5.1: The Social–Cognitive Model of ADHD, a dynamic system in which proximal and distal factors related to ADHD continually influence one another.

The proposed model is illustrated with arrows going in both directions, because the factors related to ADHD in the model influence one another synergistically. The symptoms of ADHD, such as challenges with paying attention in class, make it difficult for the student to access curriculum. Engaging with curriculum can be thought of as a form of cognitive training, where engaging in complex cognitive tasks at school actually improves EF (Zhang et al., 2019). Thus, ADHD symptoms negatively impact EF. Poor EF can contribute to maladaptive motivational patterns, as instances of failure provide the child with evidence to support his or her belief in a fixed mindset. Finally, a child's lack of motivation may contribute to the his or her proximal environment at school and at home by increasing parents' and teachers' levels of stress and frustration, which inhibit the parents' and teachers' ability to have consistent and thoughtful, positive interactions with the child and may also contribute to parents and teachers feeling as though they must remain strict in upholding their high standards. Here the spiral turns on itself again, with parenting and teaching practices impacting motivation, cognition, and symptoms.

Conclusion

This dissertation examined co-morbidity and treatment options for children with ADHD using the Dual Pathway model as a guiding framework. While these studies would have benefitted from larger and more specific samples, they supplied some evidence in support of the Dual Pathway model, motivated the creation of a new model of ADHD, and provided inspiration for future work. Given the heterogeneity of ADHD, the most promising intervention based upon this work would be a combined motivation and cognitive training intervention, using the personalized medicine approach. Participants would first be classified according to their deficit profile (i.e., according to whether they had executive dysfunction, delay aversion, or both), and then they would be randomly assigned to a motivation and cognitive training group or to an active control group. Such an intervention could also classify participants according to co-morbidity status (e.g., whether they have a reading disorder or other developmental disorder) to be able to test whether the intervention resulted in transfer to improvements in the co-morbid disorder.

In conclusion, this dissertation builds upon the field’s knowledge of co-morbidity and treatment in ADHD. My work underscores the importance of thinking beyond ADHD as a single construct. Rather, it can be considered an umbrella term for individuals with a variety of etiological and neuropsychological profiles. I found that executive functioning alone cannot explain co-morbidity and argued that multiple methods of intervention (e.g., executive function training and motivation interventions) should be developed and implemented, as children may need more than one type of treatment or a tailored treatment plan to target the diversity and complexity of their ADHD.

References

American Psychiatric Association. (2014). *Diagnostic and statistical manual of mental disorders : DSM-5. American Psychiatric Association. DSM*. https://doi.org/10.1176/appi.books.9780890425596.744053

Au, J., Buschkuehl, M., Duncan, G. J., & Jaeggi, S. M. (2016). There is no convincing evidence that working memory training is NOT effective: A reply to Melby-Lervåg and Hulme (2015). *Psychonomic Bulletin & Review*, *3*(October), 331–337. https://doi.org/10.3758/s13423-015-0967-4

Au, J., Sheehan, E., Tsai, N., Duncan, G., Buschkuehl, M., & Jaeggi, S. M. (2015). Improving fluid intelligence with training on working memory: a meta-analysis. *Psychonomic Bulletin & Review*, *105*(19), 6829–6833. https://doi.org/10.1073/pnas.0801268105

Bronfenbrenner, U., & Morris, P. a. (2007). The Bioecological Model of Human Development. *Handbook of Child Psychology*. https://doi.org/10.1002/9780470147658.chpsy0114

Carroll, J. M., Maughan, B., Goodman, R., & Meltzer, H. (2005). Literacy difficulties and psychiatric disorders: evidence for comorbidity. *Journal of Child Psychology and Psychiatry*, *46*(5), 524–532. https://doi.org/10.1111/j.1469-7610.2004.00366.x

Chronis, A. M., Pelham, W. E., Baumann, B. L., Kipp, H., Lahey, B. B., Williams, S. H., … Rathouz, P. J. (2007). Maternal depression and early positive parenting predict future conduct problems in young children with attention-deficit/hyperactivity disorder. *Developmental Psychology*, *43*(1), 70–82. https://doi.org/10.1037/0012-1649.43.1.70

Davidson, K. W., Peacock, J., Kronish, I. M., & Edmondson, D. (2014). Personalizing behavioral interventions through single-patient (N of 1) trials. *NIH Public Access*, *8*(8), 408–421. https://doi.org/10.1038/mp.2011.182.doi

DuPaul, G., & Stoner, G. (2014). *ADHD in the schools* (3rd ed.). New York, New York, USA: Guilford Press.

Haimovitz, K., & Dweck, C. S. (2017). The origins of children's growth and fixed mindsets: New research and a new proposal. *Child Development*, *88*(6), 1849–1859. https://doi.org/10.1111/cdev.12955

Jaeggi, S. M., Buschkuehl, M., Jonides, J., Shah, P., Morrison, A. B., & Chein, J. M. (2011). Short-and long-term benefits of cognitive training. *Proceedings of the National Academy of Sciences*, *108*(25), 46–60. https://doi.org/10.1073/pnas.1103228108

Jones, M. R., Katz, B., Buschkuehl, M., Jaeggi, S. M., & Shah, P. (2018). Exploring n-back cognitive training for children with ADHD. *Journal of Attention Disorders*. https://doi.org/10.1177/1087054718779230

Katz, B., Jones, M. R., Shah, P., Buschkuehl, M., & Jaeggi, S. M. (2015). Individual differences and motivational effects in cognitive training research.

Katz, B., Jones, M. R., Shah, P., Buschkuehl, M., & Jaeggi, S. M. (2016). Individual differences and motivational effects. In T. Strobach & J. Karbach (Eds.), *Cognitive Training: An Overview of Features and Applications* (pp. 157–166). Springer International Publishing. https://doi.org/10.1007/978-3-319-42662-4_15

Knight, L. A., Rooney, M., & Chronis-Tuscano, A. (2008). *Psychosocial treatments for attention-deficit/hyperactivity disorder*. *Current Psychiatry Reports* (Vol. 10).

https://doi.org/10.1007/s11920-008-0066-6

Lee, J., & Zentall, S. S. (2017). Reading motivation and later reading achievement for students with reading disabilities and comparison groups (ADHD and typical): A 3-year longitudinal study. *Contemporary Educational Psychology*, *50*, 60–71. https://doi.org/10.1016/j.cedpsych.2015.11.001

Loosli, S. V, Buschkuehl, M., Perrig, W. J., & Jaeggi, S. M. (2011). Working memory training improves reading processes in typically developing children. *Child Neuropsychology*, *18*(1), 62–78. https://doi.org/10.1080/09297049.2011.575772

Lüscher, T. F. (2013). The bumpy road to evidence: Why many research findings are lost in translation. *European Heart Journal*, *34*(43), 3329–3335. https://doi.org/10.1093/eurheartj/eht396

Maniadaki, K., & Kakouros, E. (2017). *The complete guide to ADHD: Nature, diagnosis, and treatment*. Routledge.

Melby-Lervåg, M., & Hulme, C. (2016). There is no convincing evidence that working memory training is effective: A reply to Au et al. (2014) and Karbach and Verhaeghen (2014). *Psychonomic Bulletin & Review*, *23*(1), 324–30. https://doi.org/10.3758/s13423-015-0862-z

Nigg, J. T., Willcutt, E. G., Doyle, A. E., & Sonuga-Barke, E. J. S. (2005). Causal heterogeneity in attention-deficit/hyperactivity disorder: Do we need neuropsychologically impaired subtypes? *Biological Psychiatry*, *57*(11), 1224–1230. https://doi.org/10.1016/j.biopsych.2004.08.025

Pastor, P. N., & Reuben, C. a. (2002). Attention deficit disorder and learning disability: United

States, 1997-98. *Vital and Health Statistics. Series 10, Data from the National Health Survey*, 1–12.

Pennington, B. F., Groisser, D., & Welsh, M. C. (1993). Contrasting cognitive deficits in attention deficit hyperactivity disorder versus reading disability. *Developmental Psychology*, *29*(3), 511–523.

Rabiner, D., Coie, J. D., Bierman, K. L., Dodge, K. A., Greenberg, M. T., Lochman, J. E., … Pinderhughes, E. (2000). Early attention problems and children's reading achievement: A longitudinal investigation. *Journal of the American Academy of Child and Adolescent Psychiatry*, *39*(7), 859–867. https://doi.org/10.1097/00004583-200007000-00014

Scarborough, H. S. (1990). Very early language deficits in dyslexic children. *Child Development*, *61*(6), 1728–1743.

Seymour, K. E., Macatee, R., & Chronis-Tuscano, A. (2016). Frustration tolerance in youth with ADHD. *Journal of Attention Disorders*, 1087054716653216. https://doi.org/10.1177/1087054716653216

Sonuga-Barke, E. J. S. (2002). Psychological heterogeneity in AD/HD — a dual pathway model of behaviour and cognition. *Behavioral Brain Research*, *130*, 29–36.

Sonuga-Barke, Edmund J.S. (2005). Causal models of attention-deficit/hyperactivity disorder: From common simple deficits to multiple developmental pathways. *Biological Psychiatry*, *57*(11), 1231–1238. https://doi.org/10.1016/j.biopsych.2004.09.008

Sonuga-Barke, Edmund J.S., Dalen, L., & Remington, B. (2003). Do executive deficits and delay aversion make independent contributions to preschool attention-deficit/hyperactivity disorder symptoms? *Journal of the American Academy of Child and Adolescent Psychiatry*, *42*(11), 1335–1342. https://doi.org/10.1097/01.chi.0000087564.34977.21

Visser, S. N., Danielson, M. L., Bitsko, R. H., Holbrook, J. R., Kogan, M. D., Ghandour, R. M., … Blumberg, S. J. (2014). Trends in the parent-report of health care provider diagnosed and medicated ADHD: United States, 2003-2011. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*(1), 34–46. https://doi.org/10.1002/dev.21214.Developmental

Zhang, Q., Wang, C., Zhao, Q., Yang, L., Buschkuehl, M., & Jaeggi, S. M. (2019). The malleability of executive function in early childhood: Effects of schooling and targeted training. *Developmental Science*, *22*(2), 1–14. https://doi.org/10.1111/desc.12748

APPENDIX I

Supplementary Tables for Study 2

Supplementary Table 1

Descriptive data for the cognitive measures at pre- and posttest.

	Pretest					Posttest					Pre vs. Post		
	N	*Mean*	*SD*	*Min.*	*Max.*	*N*	*Mean*	*SD*	*Min.*	*Max.*	*r*	*Cohen's d*	BF_{10}
N-back Group													
TONI	41	22.17	6.52	9	38	41	24.20	7.76	8	39	.76	0.28	3.06
SPM	41	16.95	4.32	3	24	41	17.37	4.53	6	26	.73	0.09	0.23
Following Instructions	39	4.16	1	2	6	41	4.37	0.91	2	6.50	.38	0.22	0.31
Digit Span	41	12.98	3.40	7	25	41	13.10	3.69	8	23	.75	0.03	0.18
2-back (hits-false alarms)	41	0.40	0.24	-0.13	0.93	41	0.59	0.27	-0.03	1	.48	0.74	683.57
CPT d'	39	1.87	1.03	0	4.01	41	2.28	1.29	0.02	4.54	.80	0.35	233.24
Math	41	36.07	6.14	25	51	41	36.95	5.98	24	51	.79	0.15	0.43
Reading Comprehension	40	28.73	5.24	18	42	40	29.46	4.65	18	39	.76	0.15	0.41
Reading Fluency	41	47.83	16.74	18	94	40	51.48	16.41	23	98	.91	0.22	3.26
Active Control Group													
TONI	39	21.56	7.23	7	42	39	22.15	7.62	9	39	.63	0.08	0.20
SPM	39	17.08	4.49	9	26	39	16.79	5.05	7	27	.78	-0.05	0.20
Following Instructions	39	4.08	1.07	2	6	39	4.10	1.03	2	6	.48	0.02	0.17
Digit Span	39	12.56	3.69	6	23	39	12.21	3.65	7	23	.82	-0.10	0.28
2-back (hits-false alarms)	39	0.34	0.22	-0.03	0.80	39	0.39	0.23	-0.37	0.77	.52	0.22	0.48
CPT d'	37	1.65	0.86	0	3.71	39	1.78	1.01	0.19	3.71	.73	0.14	0.59
Math	38	35.92	7.20	18	49	39	35.03	7.56	17	48	.88	-0.12	0.32
Reading Comprehension	35	28.29	5.90	11	37	32	28.77	7.24	13	43	.80	0.07	0.31
Reading Fluency	39	41.54	19.53	2	78	39	44.18	23.44	0	96	.91	0.12	0.60

Supplementary Table 2

Descriptive data for the cognitive measures at pre- and delayed posttest

	Pretest					Delayed Posttest					Pre vs. Delayed		
	N	*Mean*	*SD*	*Min.*	*Max.*	*N*	*Mean*	*SD*	*Min.*	*Max.*	*r*	*Cohen's d*	BF_{10}
n-back Group													
TONI	33	21.76	6.51	9	38	33	24.15	7.81	7	41	.64	0.33	1.84
SPM	33	16.15	4.21	3	24	33	16.97	4.90	7	26	.60	0.18	0.36
Following Instructions	31	4.17	1	2	6	33	4.35	0.95	2	6.25	.25	0.18	0.24
Digit Span	33	12.24	2.55	7	19	33	13.15	2.69	7	20	.67	0.35	1.03
2-back	32	0.34	0.22	-0.13	0.73	32	0.54	0.22	0.13	0.83	.43	0.91	185.92
CPT d'	30	1.92	0.84	0.48	3.59	31	2.33	0.99	0.34	4.54	.83	0.45	2.49
Math	33	36	5.53	26	47	33	37.67	5.68	27	50	.82	0.30	7.78
Reading Comprehension	32	28.25	5.08	18	36	33	30.67	3.76	21	39	.64	0.54	12.33
Reading Fluency	33	47.78	13.54	23	76	33	53.12	15.85	23	88	.79	0.36	19.14
Active Control Group													
TONI	31	22.87	7.51	9	42	31	25.23	7.60	7	43	.59	0.31	2.82
SPM	29	16.86	4.37	9	25	29	17.69	4.81	6	26	.76	0.18	0.40
Following Instructions	31	4.19	1.12	2	6	31	3.95	0.87	2	6	.53	-0.24	0.27
Digit Span	31	12.65	3.36	9	21	31	12.19	3.57	8	23	.83	-0.13	0.29
2-back	27	0.39	0.21	0	0.73	30	0.42	0.28	-0.03	0.90	.57	0.12	0.65
CPT d'	26	1.94	0.76	0	3.06	29	1.91	1.05	0	3.59	.50	-0.03	0.34
Math	29	36.90	7.05	24	49	30	36.87	8.06	23	52	.77	0.00	0.24
Reading Comprehension	26	29.81	4.98	17	39	27	30.35	5.27	20	41	.72	0.11	0.59
Reading Fluency	30	45.43	20.84	2	78	30	53.13	24.27	3	98	.89	0.34	89.66

Supplementary Table 3

Descriptive data for parent rating scales, including only participants who had data for both pretest and delayed posttest.

	Pretest					Delayed Posttest					Pre vs. Post		
	N	*Mean*	*SD*	*Min.*	*Max.*	*N*	*Mean*	*SD*	*Min.*	*Max.*	*r*	*Cohen's d*	BF_{10}
n-back Group													
CBCL													
Competence	26	44.62	9.14	32	70	26	43.38	9.75	28	63	.61	-0.13	0.27
Internalizing	26	54.15	9.54	41	73	26	53.35	11.30	34	71	.69	-0.08	0.22
Externalizing	26	53.69	11.19	34	73	26	52.69	10.06	40	76	.83	-0.09	0.28
Syndrome Scale	26	58.27	8.50	44	73	26	56.15	8.82	42	71	.86	-0.24	1.28
Attention Problems	26	67.15	8.32	53	90	26	62.38	5.90	52	76	.80	-0.66	411.02
Affective Problems	26	57.85	7.08	50	73	26	58.88	6.99	50	75	.66	0.15	0.30
Anxiety Problems	26	56.73	7.82	50	78	26	56.62	7.77	50	73	.69	-0.01	0.21
Somatic Problems	26	53.81	5.45	50	65	26	52.96	4.50	50	64	.38	-0.17	0.27
ADHD Problems	26	64.88	6.84	55	80	26	60.65	5.40	50	70	.60	-0.69	43.62
Defiant Problems	26	57.12	7.64	50	77	26	55.46	7.38	50	77	.81	-0.22	0.87
Conduct Problems	26	55.54	6.96	50	70	26	54.65	8.00	50	81	.88	0.40	0.39
School Problems	26	39.65	7.92	27	55	26	42.19	8.04	29	55	.82	-0.12	4.05
BRIEF													
Inhibition	21	19.00	5.67	11	29	21	17.62	4.98	10	27	.83	-0.26	1.17
Shifting Tasks	21	12.95	3.61	8	19	21	12.90	3.90	8	20	.84	-0.01	0.23
Emotional Control	21	16.57	4.68	11	26	21	16.38	4.73	10	30	.75	-0.04	0.24
Initiation	21	15.43	3.12	10	20	21	14.48	3.43	8	20	.81	-0.29	1.44
Working Memory	21	23.86	4.05	14	28	21	21.14	4.55	12	29	.69	-0.63	24.14
Planning/ Organization	21	25.57	6.28	12	33	21	24.67	5.62	14	34	.70	-0.15	0.33
Organization of Materials	21	14.10	2.57	10	18	21	14.10	2.90	7	18	.60	0	0.23
Task and Self-Monitoring	21	17.38	3.35	11	23	21	16.10	3.45	10	23	.67	-0.38	1.44
Behavioral Regulation	21	48.52	11.20	32	69	21	46.90	11.26	28	77	.80	-0.14	0.37
Metacognition Index	21	96.33	15.50	68	115	21	90.71	16.91	62	113	.80	-0.42	2.76
Global Executive	21	144.86	22.28	108	184	21	137.67	24.92	92	185	.81	0.30	1.70
Emotional Control	21	52.10	10.83	38	75	21	52.00	11.24	37	85	.73	0.01	0.24
Working Memory T-Score	21	68.90	9.61	45	83	21	63.67	11.71	40	83	.74	-0.49	12.82
Regulation T-Score	21	56.71	11.24	39	78	21	55.33	11.43	39	87	.79	-0.12	0.44
Executive Function	21	62.76	9.77	45	84	21	59.86	11.18	41	86	.84	-0.28	2.69

Connors													
Inattention Problems	25	21.00	7.38	8	35	25	15.92	15.925.	4	34	.70	-0.41	136.34
Hyperactivity	25	9.04	5.48	0	19	25	7.28	40	0	25	.73	-0.32	1.62
Opposition	25	8.24	6.11	0	18	25	7.16	7.10	0	22	.85	-0.16	0.52
Anxiety Problems	25	3.76	3.06	0	12	25	3.56	3.25	0	12	.62	-0.06	0.22
Perfectionism	25	3.00	2.45	0	8	25	2.68	1.91	0	7	.63	-0.15	0.29
Social Problems	25	3.48	2.65	0	11	25	3.56	3.75	0	14	.46	0.02	0.21
Psychosomatic Problems	25	1.36	2.20	0	8	25	1.56	1.98	0	7	.66	0.10	0.24
ADHD Index	25	21.60	6.39	7	32	25	16.44	7.03	4	29	.67	-0.77	306.91
Restless/ Impulsivity	25	9.52	3.58	2	16	25	7.76	3.54	1	16	.72	-0.49	12.80
Emotional Liability	25	2.32	2.72	0	9	25	1.68	2.01	0	8	.70	-0.27	0.70
DSM Inattentive	25	17.20	5.64	6	26	25	13.28	6.03	2	27	.68	-0.67	91.33
DSM Hyperactivity	25	10.88	6.12	0	20	25	8.08	5.48	0	24	.77	-0.48	20.76
Active Control Group													
CBCL													
Competence	21	42.05	9.45	28	58	22	43.18	10.69	28	72	.86	0.11	0.32
Internalizing	22	55.27	12.35	33	73	22	53.45	11.80	33	73	.85	-0.15	0.46
Externalizing	22	53.18	9.51	34	75	22	52.86	9.22	34	72	.84	-0.03	0.23
Syndrome Scale	22	59.91	8.45	43	73	22	57.64	9.12	39	73	.87	-0.26	2.15
Attention Problems	22	70.95	9.12	55	83	22	68.45	10.26	53	92	.53	-0.26	0.44
Affective Problems	22	61.41	8.14	50	75	22	59.18	7.27	50	75	.67	-0.29	0.71
Anxiety Problems	22	55.55	8.06	50	75	22	54.59	7.59	50	73	.85	-0.12	0.37
Somatic Problems	22	57.45	8.27	50	77	22	57.45	8.29	50	73	.78	0.00	0.22
ADHD Problems	22	65.64	7.77	52	80	22	64.45	8.20	52	80	.61	-0.15	0.29
Defiant Problems	22	55.77	6.11	50	70	22	55.41	6.06	50	70	.83	-0.06	0.25
Conduct Problems	22	55.23	7.08	50	77	22	54.59	6.16	50	73	.91	-0.10	0.35
School Problems	21	41.10	8.44	27	54	22	42.36	6.84	30	55	.70	0.16	0.26
BRIEF													
Inhibition	23	20.00	5.02	10	28	23	19.61	5.45	10	30	.84	-0.07	0.26
Shifting Tasks	23	14.78	3.36	9	19	23	14.13	3.20	8	19	.49	0.20	0.33
Emotional Control	23	17.26	4.83	10	26	23	16.74	4.37	10	26	.49	-0.11	0.25
Initiation	23	16.52	3.06	12	23	23	16.87	2.88	13	23	.53	0.12	0.26
Working Memory	23	25.61	3.31	19	30	23	24.17	3.33	18	30	.66	-0.43	2.84
Planning/ Organization	23	27.13	6.08	17	36	23	27.43	4.89	18	36	.71	0.05	0.23
Organization of Materials	23	15.48	2.69	11	18	23	14.78	2.89	9	18	.68	0.25	0.57

Task and Self-Monitoring	23	19.09	3.38	13	24	23	18.91	3.19	14	24	.83	-0.05	0.24
Behavioral Regulation	23	52.04	10.38	32	67	23	50.48	10.87	34	71	.66	-0.15	0.30
Metacognition Index	23	103.83	15.04	77	131	23	102.35	13.07	73	127	.79	-0.10	0.29
Global Executive	23	155.87	23.13	112	198	23	152.83	22.13	113	196	.75	-0.13	0.32
Emotional Control	23	53.09	10.37	36	71	22	52.91	10.23	37	71	.37	-0.02	0.25
Working Memory T-Score	23	73.04	7.55	58	89	22	70.45	8.71	54	89	.73	-0.32	1.55
Regulation T-Score	23	59.91	10.16	40	78	22	59.14	11.56	42	81	.67	-0.07	0.32
Executive Function	23	66.74	9.59	47	87	22	66.14	9.84	47	87	.79	-0.06	0.34
Connors													
Inattention	22	22.59	8.92	1	36	22	18.91	7.40	10	33	.66	-0.45	2.85
Hyperactivity	22	10.18	6.15	1	20	22	8.91	5.37	0	22	.76	-0.22	0.56
Opposition	22	8.36	6.21	0	24	22	7.41	4.86	1	17	.77	-0.17	0.39
Anxiety Problems	22	4.59	4.81	0	16	22	3.73	4.57	0	14	.91	-0.18	1.27
Perfectionism	22	2.27	2.19	0	7	22	2.00	1.48	0	6	.55	-0.14	0.28
Social Problems	22	4.09	4.29	0	13	22	3.14	3.56	0	13	.71	-0.24	0.56
Psychosomatic Problems	22	2.64	2.90	0	10	22	2.36	2.79	0	9	.82	-0.10	0.29
ADHD Index	22	23.27	7.81	8	33	22	19.18	7.42	8	34	.53	-0.54	3.18
Restless/ Impulsivity	22	11.59	4.45	2	19	22	9.27	4.67	2	18	.60	-0.50	3.62
Emotional Liability Index	22	1.95	1.89	0	7	22	1.68	1.64	0	5	.69	-0.15	0.32
DSM Inattentive	22	18.41	6.22	4	27	22	15.05	5.52	7	26	.49	-0.57	3.62
DSM Hyperactivity	22	11.73	6.94	0	23	22	10.05	5.74	1	23	.76	-0.26	0.80

Supplementary Table 4

Correlations of outcome measures at pretest, training gain, and gain scores from pretest to posttest for the training group

		1	2	3	4	5	6	7	8	9	10	11
1	CPT d' Pretest	1										
2	CPT Errors of Commission Pretest	-.93**	1									
3	Working Memory Pretest	.44**	-.33*	1								
4	School Tasks Pretest	.29	-.12	.75**	1							
5	Reasoning Pretest	.32*	-.16	.45**	.56**	1						
6	Training Gain	.16	-.05	.34*	.16	.09	1					
7	CPT d' Gain	-.05	.02	.30	.24	-.13	.32	1				
8	CPT Errors of Commission Gain	.07	-.07	-.40*	-.38*	.06	-.34*	-.86**	1			
9	Working Memory Gain	.26	-.25	-.31	-.06	.12	-.10	-.11	.26	1		
10	School Tasks Gain	.31	-.33*	-.08	-.50**	-.28	.21	-.12	.23	-.06	1	
11	Reasoning Gain	-.25	.19	.16	.11	-.30	.26	.22	-.30	-.18	.07	1

Note: CPT = Continuous Performance Task

Supplementary Table 5

Correlations between outcome measures at pretest, training gain, and outcome measure gains from pretest to delayed posttest

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	CPT d' Pretest	1																
2	CPT Errors of Commission Pretest	-.93**	1															
3	Working Memory Pretest	.44**	-.33*	1														
4	Inattention & Hyperactivity Pretest	-.22	.20	-.28	1													
5	Opposition & Defiance Pretest	-.13	.10	-.24	.58**	1												
6	EF Pretest	-.24	.10	-.24	.71**	.59**	1											
7	School Tasks Pretest	.29	-.12	.75**	-.39*	-.27	-.29	1										
8	Reasoning Pretest	.32*	-.16	.45**	-.11	-.041	.05	.56**	1									
9	Training Gain	.16	-.05	.34*	-.05	-.38*	-.47**	.16	.09	1								
10	CPT d' Gain	-.43*	.34	.16	-.22	-.20	-.25	.02	-.40*	.28	1							
11	CPT Errors of Commission Gain	.12	-.21	-.41*	.10	.019	.27	-.28	.25	-.33	-.84**	1						
12	Working Memory Gain	-.09	-.10	-.55**	-.09	-.101	.02	-.35	-.06	-.17	.05	.31	1					
13	Inattention & Hyperactivity Gain	.13	-.08	-.19	-.38	.06	.04	.18	.21	-.41*	-.34	.30	.26	1				
14	Opposition & Defiance Gain	.01	-.12	.08	.06	.23	.01	.17	.19	-.08	-.22	-.01	.03	.24	1			
15	EF Gain	.28	-.26	-.32	.05	.04	-.15	-.16	-.09	.12	-.37	.21	.18	.49*	.24	1		
16	School Tasks Gain	.51**	-.55**	.01	-.17	-.33	-.28	-.39*	-.29	.12	-.08	.10	.26	.04	.08	.26	1	
17	Reasoning Gain	-.09	-.07	.17	-.21	-.34	-.49*	-.06	-.33	.41*	-.50**	-.22	.16	-.29	.02	-.12	.33	1

Note: EF = executive functions; CPT = Continuous Performance Task

APPENDIX II

Parent Packet for the Experimental (Motivation) Group

University of California – Irvine & University of Michigan's

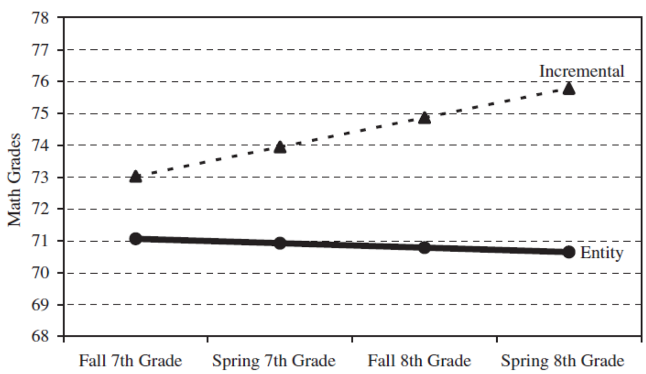
Intervention for School Success

Parent Packet

Mindsets matter…

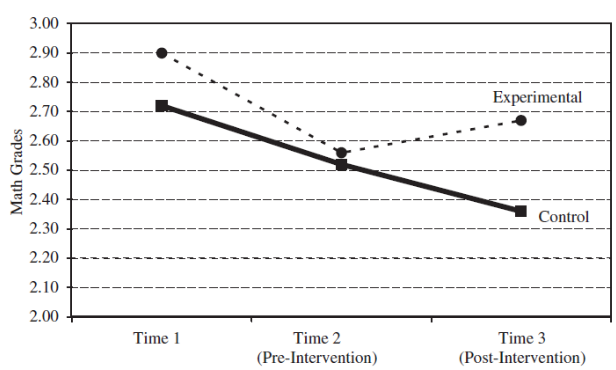
From Dr. Lisa Blackwell and colleagues' paper "Implicit Theories of Intelligence Predict Achievement Across an Adolescent Transition: A Longitudinal Study and an Intervention."

Incremental theory of intelligence → positive effort beliefs and learning goals → fewer ability-based, helpless attributions, more positive strategies → improved grades.



Typical students endorsing fixed or growth mindsets performed similarly until middle school. These motivational beliefs may not have an effect until challenge became present and successes were more difficult to achieve. Compared to students with an entity (or "fixed") mindset, students with an incremental (or "growth") mindset showed improvement in math grades in the face of difficulty.

…and can be changed!



In a separate intervention study, students with a downward grade trajectory were recruited to an intervention workshop. One group (Experimental, the dotted line) was taught that **learning changes the brain by forming new connections** and that **students are in charge of this process.** Following the intervention, this group showed a positive recovery in math grades, while the control group grades continued to decline.

Blackwell and colleagues proposed that an incremental (growth) mindset leads to **positive beliefs about effort and learning goals**. Students with this mindset focus less on the limits of their ability or the helplessness of their situation and focus instead **on positive strategies for overcoming challenges.** This is what ultimately leads to the improved grades.

“When do you feel smart?”

(from Dr. Carol Dweck’s book, *Mindset, The New Psychology of Success*)

“We asked people, ranging from grade schoolers to young adults, ‘When do you feel smart?’ The differences were striking.”

People with the fixed mindset said:

“It’s when I don’t make any mistakes.”

“When I finish something fast and it’s perfect.”

“When something is easy for me but other people can’t do it.”

It’s about *being perfect right now*. In the fixed mindset it’s not enough to just success. It’s not enough just to look smart or talented. You have to be pretty much flawless. And you have to be flawless right away. When do people with a fixed mindset thrive? When things are safely within their grasp. If things get too challenging when they’re not feeling smart or talented, they lose interest.

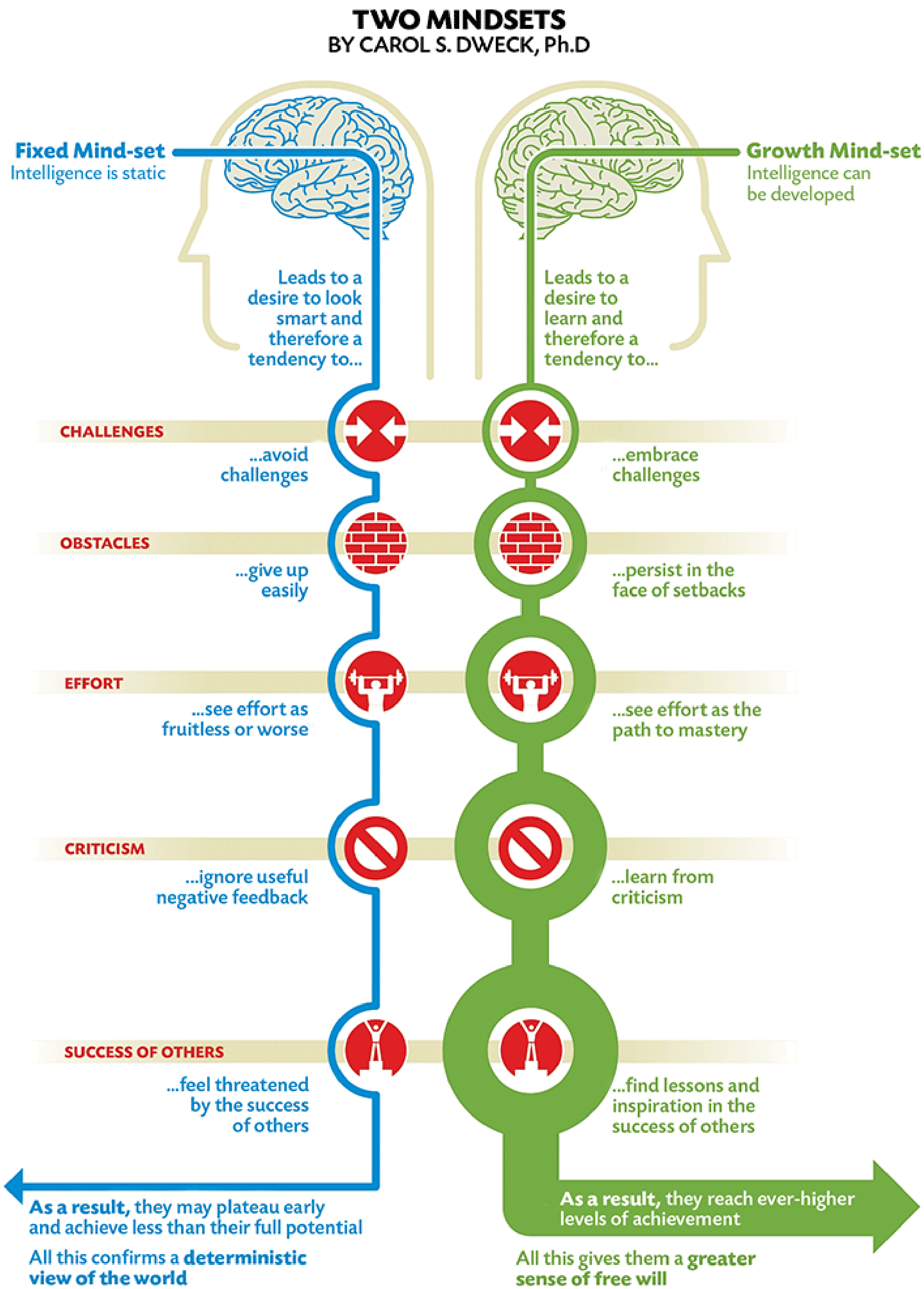
People with the growth mindset said:

“When it’s really hard and I try really hard, I can do something I couldn’t do before.”

“When I work on something a long time and I start to figure it out.”

For people with a growth mindset it’s not about immediate perfection. It’s about *learning something over time*—confronting a challenge and making progress. People with a growth mindset thrive when they’re stretching themselves.

Growth vs. Fixed Mindset



Praise

Not all praise is good….

Some students believe their intellectual ability is fixed and … become excessively concerned with their level of intelligence. Typically, these students will seek tasks that prove their intelligence and avoid ones that will not. Other student believe their intellectual ability is something they can develop through hard work and education — commonly called a growth mindset.

Praising students' intelligence forms a vulnerable fixed mindset, instead of the intended motivation and resilience. Rather, educators should focus on providing effort or "process" praise, which fosters motivation by telling students what they have done and what they need to do to continue to be successful.

Instead of:	Try saying:
I'm not good at this	What am I missing?
I'm awesome at this	I'm on the right track
I give up	I'll use a different strategy.
This is too hard.	This might take some time and effort
I can't make this any better	I can always improve, so I'll keep trying.
I just can't do math.	I'm going to train my brain in math.
I made a mistake.	Mistakes help me to learn better.
[Person] is so smart. I will never be that smart.	I'm going to figure out how [person] does it so I can try it!
It's good enough	Is it really my best work?
Plan A didn't work.	Good thing the alphabet has 25 more letters!
The more effort I have to put in, the less m ability	The more effort I put in, the more I'm learning!
Failure is catastrophic	Failure is an opportunity
There's not enough time	What can I do with the time I have?/ How can I make time for this?
Focus on proving	Focus on improving
I can't do it	I can't do it YET

Labels that Judge:

- Smart
- Cute
- Great
- Fast
- Vest
- Pretty
- Good
- Quick
- Clever
- Beautiful
- Lovely
- Intelligent
- Right
- Amazing
- The best
- Better than ______(another person)

Words that encourage:

- Wow! ☺
- Look at that!
- Tell me more about it.
- Show me more.
- How did you do that?
- Let's see what you did.
- How do you feel about it?
- How did you figure that out?
- I see that you ________. (be specific)
- That looks like it took a lot of effort.
- What do you plan to do next?
- *high five!*
- I can tell you put a lot of effort into this! (Good job.)
- I bet we can learn something from this mistake.
- It might be hard, but let's keep trying.

Further Reading and References

On Growth mindset:

Blackwell, L., Trzesniewski, K.H.,and Dweck, C.S. (February 2007). "Implicit Theories of Intelligence Predict Achievement Across an Adolescent Transition: A Longitudinal Study and an Intervention." *Child Development*. V 78: 246 – 263. http://mtoliveboe.org/cmsAdmin/uploads/blackwell-theories-of-intelligence-child-dev-2007.pdf

Dweck, C. 2006. *Mindset: The New Psychology of Success*. Random House. New York. ISBN 1- 4000-6275-6

On Praise and Perseverance:

Reaching IN…Reaching OUT. (2012) "Keep Trying (Perserverance)" Accessed December 8, 2016 from http://www.reachinginreachingout.com/resources-parentprofessionals.htm

Ferguson, M. 2013. Praise: "What does the Literature Say? What are the Implications for Teachers?" *Kairaranga.* 14-2: 35 – 39. http://files.eric.ed.gov/fulltext/EJ1025643.pdf

Pajaro Valley Unified School District. (November 2007) "Understanding Mindsets". Accessed November 15, 2016 from http://documentslide.com/documents/understanding-mindsets-.html

APPENDIX III

Parent Packet for the Control (Study Skills) Group

University of California – Irvine & University of Michigan's

Intervention for School Success

Parent Packet

Study Environments

Transition from elementary to middle school and middle to high school is marked by growing independence in the school climate. Students are increasingly in charge of their own class schedule and, more importantly, their own learning.

(From Robert Bjork's "How to Succeed in College: Learn How to Learn")

"Don't always study at your desk in your room. Why? Contextual variation results in higher recall and lower retroactive interference. Introduce variety: Study in the library, alone, with friends, with and without background noise, in your room, indoors, outdoors. This will maximize the number of retrieval cues available for recall of any piece of information (and so increase recall) and result in less cue overload (fewer items of information associated per cue)."

Things to look for in a study environment:

- Quiet environment
- Supplies readily available
- Space to put books/ reference materials and spread out.
- Close to other references/ people who can help.
- Food easily accessible
- Comfortable (but not too comfortable) seating

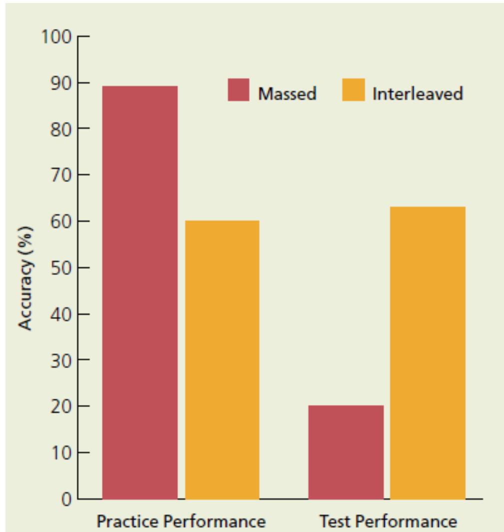
Ideas for places to study:

- Home:
    - At a desk in their room
    - Living room/ dining room table
- Library
- School study room/ classroom (may have whiteboards)
- Local café.

Spacing and Interleaving

(from John Dunlosky's article "Strengthening the Student Toolbox: Study Strategies to Boost Learning)

Interleaved practice involves not only **distributing practice across a study session** but also **mixing up the order of materials.** …Distributed practice trumps massed practice, but [distributed practice] typically refers to distributing the practice of the *same* problem across time. Thus, for spelling, a student would benefit from writing each word on a worksheet once, and then cycling through the words until each has been spelled correctly several times. Interleaved practice is similar to distributed practice in that it involves spacing one's practice acorss time, but it specifically refers to practicing *different types* of problems across time.



Accuracy at solving problems during practice session and on the delayed criterion test.

Effective Studying

(adapted from Robert Bjork's article "How to Succeed in College: Learn How to Learn")

Assume that you have a younger sibling who is going to be a college freshman next Fall. Assume further that this particular sibling actually believes that you may have learned something – that is, that you may be a source of good advice on how to succeed in college. Drawing on concepts and phenomena covered in this course, list six different recommendations you would make to your sibling (with respect to notetaking, study techniques, exam performance, and so forth).

A few years ago, [Bjork] asked this question on a final exam in [his] graduate course on human learning and memory…. [and] was impressed with how well a number of students had answered that particular question. Many of the answers were not only good answers, but were also characterized by a certain enthusiasm…One student commented, for example, that "first of all, I would explain to my sister that people are not, in general, good judges of what's best for them in studying and learning. So she should listen to me very carefully, since some recommendations may seem counterintuitive."

Instead of:	Try to:
On Note Taking	
Writing down everything the teacher says	Wait and write down only main ideas.
Copying the book verbatim	Summarize the main idea from the paragraph in your notes.
Accepting everything taught	Ask questions. Write down things that don't make sense and get them explained after.
Memorizing everything	Figure out how and why things work; learn general concepts
On Studying	
Reading the book after class or not at all.	Read the material in advance.
Studying in the same place	Introduce variety to where you study
Studying the same thing for hours on end.	Interleave your subjects in 30-50 minute sessions with short breaks.
Cram studying everything at once	Take breaks and space out your study sessions.
Just reading	Make up questions and test yourself on the material
Putting off hard projects or subjects.	Start with the hardest things.
Highlighting everything	Highlight only headings or main points.
Waiting until the end of a chapter or unit to consolidate notes.	Review notes for a class as soon as you can after making them so you can fill in missing information, correct anything you wrote wrong and check handwriting.
Isolating your studying	Connect what you learn to things you already know and are familiar with.
Always working silently	Explain what you're learning to a friend or sibling. You'll learn what you don't know by what you can't explain.
On Preparing for and Performing on an Exam	
Studying in just one session	Space your studying over a few days before the exam.
Stressing over a poor exam score	Review what you missed, what you did wrong, and make sure you know how to do better.
Just reviewing what the teacher taught.	Read the textbook, look up more information online. Sometimes it even helps connects concepts better.

Help Your Student Make the Grade

(from Willis Jepson Middle School's "Study Skills Packet")

- **Your attitude towards school is very significant in your child's mind. Always be positive about school and the value of getting an education.**

- **Don't Let Your Child Miss School**
  - Do whatever it takes to keep your child in school. This may even mean taking a day or so off from work to sit with your child in the classroom if he or she has been 'ditching' school.
  - Be sure to buy an alarm clock and allow plenty of time for your student to get up, eat a healthy breakfast and arrive to school on time. Students who are continually late arriving to school get so far behind in schoolwork they give up trying.

- **Have Great Expectations**
  - A study conducted by the University of Florida indicates that one of the most important things parents can do for children is to expect them to achieve.
  - When parental expectations are combined with teacher expectations, students DO ACHIEVE.
  - Encourage and support through positive communication and action. Negative comments may help you vent frustrations, but they don't help your student grow and learn.
  - Be sincere and truly expect the very best from your children.

- **Focus on Strengths**
  - Find activities that your student can excel in and enjoy, and then support their continued success in these areas. "The key is to help your student develop his or her own identity in terms of the things he or she does well."

- **Become Involved**
  - Attend Back-To-School night.
  - Know the dates of all parent conferences and when progress report notices will be sent home. Remember that good news travels fast, but bad news may not travel at all.
  - Ask how much homework is expected and how much time should be spent on it each night.

  - **Know the teacher:** if a problem comes up, talk to the teacher. Teachers appreciate you coming to them directly. Bring your child along for the meeting.

- **Balance Work and Play**
  - Personal satisfaction and happiness are important qualities in the successful learner. "Never underestimate the value of play for creating energy and renewal for less enjoyable, but necessary tasks.

- **Values are Vital**
  - Students no longer support traditional sources of authority. Students instead turn to their peer group to decide what is right and wrong.
  - Students still look to their parents as role models; don't show them a "winning is everything", a "me-first attitude" and a "get ahead at any cost" way of living.
  - Teachers spend nearly 40 percent of their day dealing with discipline problems. Little teaching can go on in such classrooms; students suffer academically while teachers burn out.

  - Set a positive example by reading books, newspapers and "studying" while they are.

Effectiveness of Techniques

(from John Dunlosky's article "Strengthening the Student Toolbox: Study Strategies to Boost Learning)

Technique	**Extent and Conditions of Effectiveness**
Practice Testing	Very effective under a wide array of situations.
Distributed practice	Very effective under a wide array of situations.
Interleaved Practice	Promising for math and concept learning, but needs more research
Elaborative interrogation	Promising, but needs more research
Self-explanation	Promising, but needs more research
Rereading	Can be helpful, but time could be better spend using another strategy.
Highlighting and underlining	Not particularly helpful, but can be used as a first step toward further study.
Summarization	Helpful only with training on how to summarize
Keyword mnemonic	Somewhat helpful for learning languages, but benefits are short-lived.
Imagery for text	Benefits limited to imagery-friendly text; needs more research

Further Reading and References

On Study Skills:

Bjork, R. A. (March 2001). "How to Succeed in College: Learn How to Learn". *Observer*. V 14: 3. http://www.psychologicalscience.org/observer/0301/prescol.html

Dunlosky, J. (2013). "Strengthening the Student Toolbox: Study Strategies to Boost Learning". *American Educator.* V37: 12 - 21

Son, L.K., (May 2004). "Spacing One's Study: Evidence for a Metacognitive Control Strategy" *Journal of Experimental Psychology: Learning, Memory and Cognition.* V 30: 3: 601 – 604.

Willis Jepson Middle School. "Study Skills Packet". Accessed May 12, 2017. From www.legacyprep.org/userfiles/141/Classes/1259/Study%20Skills%20Packet.doc

On Time Management and Prioritizing:

Jar of Life animation video: https://www.youtube.com/watch?v=v5ZvL4as2yo

APPENDIX IV

Lesson Plans for the Experimental (Motivation) Group

Motivation Lesson 1 — Growth / improvement always possible

OVERVIEW

Icebreaker: Grade, favorite subject in school.

Core message: Don't give up + we might not be great at everything, but we can improve. (Not everyone can be an Olympic runner, but everyone can get better at running.)

Activity: Mojo video clip, write a letter to Mojo about what he should do.

Conversation starters:

- Story about how you tried really hard at something. What happened? Did you improve?
- What do you think Mojo should do? Hang in there? Give up?
- What do you so when trying harder just isn't enough?
- What do you enjoy/ want to get better at? Or-- what do you want your brain to get better at?
- How did you get better at the things you already are good at?
- What about when trying harder just isn't enough?
  - Define your goals. What exactly do you want to achieve?
  - Ask for help from someone else, even just to keep you accountable.
  - Break it into smaller tasks.
  - Try a different method/ approach it from a different angle/ Try a different strategy.
  - What's getting in your way?
    - How can you solve these sub-problems?
  - What's your motivation?

Homework: Between now and next time, try really hard at something, and tell us next time.

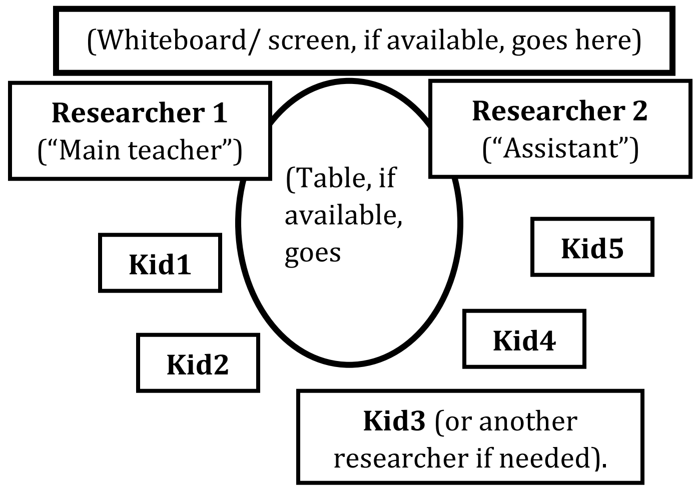
Activity	Supplies	Time (min)
Introductions		10
Mojo Video	-Device to play video on -Screen -Mojo Video	5
Discussion Questions		15-20
Letter to Mojo/ yourself	-paper -colored pencils	15-20

LESSON PLAN

Introductions		10

Greet their parents as they come and bring the child into the room. Introduce your name and try to talk to them and make them comfortable as people arrive.

Have students sitting in a rough circle:



After everyone has had a chance to arrive and talk a little bit:

>> Hello everyone! So to start out, we're all going to introduce ourselves. Let's say your <u>name, grade in school,</u> and <u>favorite school subject.</u> I'll start. My name is Hello Kitty, my favorite school subject was language arts, and I'm in my third year of graduate school—can anyone guess what grade that is?

Participants: 5^{th}! 10^{th}! 12^{th}, etc etc etc.

(Someone will guess it or you just can walk them through it like: Well when you graduate high school you're in 12^{th} grade. Plus 4 years of college, then another 3 years... (19!) That's right, 19^{th} grade. Can you imagine being in school that long?)

*[**The other researcher** goes, then continue around the circle. Feel free to make short comments about their hobbies, particularly to build rapport.]* (Oh I like reading too! What are you reading now?/ What's your favorite sport? What belt are you in martial arts? What's wingchun? That sounds cool, let's talk about that more later!)

Mojo Video	-Device to play video on -Screen -Mojo Video: https://ideas.classdojo.com/f/growth-mindset-1	5

>> Ok, so for today, I have a little video I want to watch with you.

If the kids are older: "It's a little silly and for younger kids, but I think it's kinda funny, so we're gonna watch it anyway."

[***Play*** *Mojo video****. Pause*** *when Mojo decides to give up*. (~:44 seconds, right after "It seemed the only reasonable thing to do was pick his things and leave forever.") (Could also pause at 1:01, right after "And I realized today that I'm not.")]

>> Pause: What do you think? What do you think Mojo should do?

[Get student responses. Repeat after them to validate them, ask them for thoughts but don't offer right/ wrong/ your ideas yet.] Ok, let's see what his friend thinks.

[Finish Mojo video]

Discussion Questions		15-20

>> After video: What did you think of that video?

Let's recap:

- What happened to Mojo in the beginning of the story?
  - *Looking for something like:* Math suddenly felt really hard and Mojo wanted to give up.
- What did Mojo's friend Katie tell him?
  - **Prompt:** What was the secret to being smart the neuroscientists discovered?
  - *Looking for:* The brain is like a muscle and if you work hard at something the brain can get stronger!
- Do you think Mojo can become better at math?
- Can you?

Talk about a time when they tried really hard at something, practiced, and got better at it. Have one teacher use an example of something they were already good at and another talk about something that was originally very hard. Emphasize this structure: ***realizing difficulty, deciding it's important and you want to get better, practicing, improvement.***

#Storytime: A year ago I really didn't like running. But I had to run if I wanted to do the triathlon, so I started practicing a lot. Even though it was tough at first, it got easier as I kept running and now I actually like running!

Letter to Mojo/ yourself	-paper -colored pencils	15-20

>> Instructions: So now we're going to do write a letter to Mojo about what you think he should do and why. [Esp. for older kids:] You don't have to write it to Mojo. For example, if you have a friend who is thinking about giving up on something that means a lot to them, you could write it to them instead. Or if you want to write the letter to your past self about something, you can do that.

[Fold a piece of paper like a card and have them write on the inside. If students need a little more scaffolding, divide them into groups with a supervising researcher. Feel free to prompt them if they are struggling to think of things to write:]

- What do you think Mojo should do? (Give up/ hang in there)
  - Why?
- What do you think he can do if he's having trouble with his math?)
  - (Ask for help, break up the problems into little problems he knows what to do about).

>> After writing: If you're finished writing, let's draw something on the front.

[If no one brings this up before, have the assistant bring up this scenario while people are coloring/ drawing the drawing. If they finish that too, you can give them another paper to draw on.]:

>> When trying harder just isn't enough (Assistant): Hey, I have a question to ask the group. So recently I've been [playing the flute], but no matter how many times I try, I just can't seem to sound any better. I've really been trying and practicing every day, but it doesn't seem to be enough. Do you guys have any advice?

Possible ideas:

- Define your goals. What exactly do you want to achieve?
- Ask for help from someone else.
  - Even just to keep you accountable.
- Break it into smaller tasks.
  - What are some small steps you can take to reach that same goal?
    - (Mini sucks at waking up and doesn't get anything done—but regardless of how late she wakes up, she can still get something done right when she gets up)
- Try a different method/ approach it from a different angle.
  - Try a different strategy.
- What's getting in your way?
  - How can you solve these sub-problems?
- What's your motivation?

>> Other casual conversation topics:
- What do you enjoy and want to get better at?
- What do you want your brain to get better at?
- How did you get better at the things you already are good at?

Closing remarks	-paper -colored pencils	

At the end of the lesson: Hey, I like your card! Can I take a picture of it? [Take picture for evidence.]

>> Summary points: What did we talk about today? *Ask kids for these points or remind them.*

- Don't give up when things get hard.
- When we try really hard, our brains get stronger and we get better at things.
- Trying hard can also mean finding different strategies.

>>Homework: Between now and the next time we meet, I want you to try really hard at something. Next time, I'll ask you to tell me how it went, ok?

Motivation Lesson 2 — Neurons

OVERVIEW

Icebreaker: Fun fact/ what they tried really hard at.

Core message: Relating achievement to effort and effort to neurons. Something is actually happening in your brain when you try!

Activity: Neuron powerpoint, make a beeswax neuron, show them n-back powerpoint.

Questions/ conversation starters/ other things to talk about:

- Ask them if they have any questions about the brain.
- Myelin story: white vs gray neurons.
- What do you want your brain to be better at?

Activity	**Supplies**	**Time (min)**
Introductions		10
Interventions	-screen -n-back powerpoint.	10
Neuron powerpoint	-screen -neuron powerpoint	15
Make a neuron	-beeswax -neuron plushy -toaster oven	10

WARM BEESWAX IN TOASTER OVEN SO IT'S READY TO GO

LESSON PLAN

Introductions		10

Continue to establish rapport with the students and make them comfortable. When starting:

>> Welcome back! Just in case, let's go around with our name and a fun fact. So I'm Hello Kitty and my fun fact is that no one draws me with a mouth.

Continue around the circle, going in the direction of the other researcher.

>> Recap: Can anyone remind us what we were talking about last time?

Participants might mention: Mojo video, important to try hard, we can get better, the brain is like a muscle.

Right, we talked about how we can get better when we try. Did anyone try really hard at something between last time and this time? For example, I'm drawing a picture and had to try really hard to get the character's face right.

Possible responses and follow up responses:

- I had to try really hard at ___.
  - Great! I'm really proud of you for trying so hard.
  - How did it work out?
  - Do you think you got better at ___?
  - What problems did you run into while you were trying?
  - ____ sounds important to you! Do you usually enjoy/ do ____?
- I didn't have to try for anything.
  - Then let's think of something you'd like to get better at or are working to get better at.
  - What kind of problems do you think you'll run into?
  - How did you get good at what you already know? (Practice)

Interventions	-n-back powerpoint	10

https://docs.google.com/presentation/d/1HpXKfPc17-bRXU7OqKhRrj1YwWExj7qkoEqeAQxAxB8/edit#slide=id.g1da303fc8d_0_197

>> Today we're going to talk about some evidence for this and understand what is really going on in our brains when we say it's getting stronger.

Talk about how kids ADHD n-back intervention study (i.e., Masha's paper)

>>N-back: Some of you might have played this game with us before (show n-back). In this game you have to hold in mind what the last few objects were. This uses something called your working memory.

Go to power point presentation, use notes there as script. (Also copied here)

N-back and What is an N-back: To show you how the Nback game works, we'll be using the game Minecraft.

Characters slide: Some of the block types might be ground, snow, pig, and human. For now, we can call the human [name of one of the researchers or kid].

Level 1: Let's start with a level 1 n-back. In level 1, we are looking to see if the current block matches the block from 1 step before. So we start with the pig *[go through the level one slides, saying the name of the blocks together. At the second land (1-back)]:* Right, this ground block matches the one right before it, so we tap this. *[Go through the other level 1 slides]*

Level 2: Now let's try level 2! Just to make sure, what does level 2 mean? [matching the block 2 blocks before]. Good job; let's try this. So we have ground block, [human], enderman, [human]! *Click once more for all 4 images to appear]* Which pair here represents a 2-back? [the human] Nice! So it's both humans because they are 2 spaces apart. So when you play the game, you would tap that second human when it comes up.

>>By practicing with your working memory a lot, you make it stronger. When people play this game, they get better at remembering stuff and focusing/paying attention. We even had kids with ADHD play the n-back, and they were able to pay attention and remember stuff better than before they played the n-back. But it took lots of hard work and effort, because this game really isn't easy.

Neuron powerpoint	-neuron powerpoint: http://bit.ly/2qctJuM	15

Load up the neuron powerpoint and make sure students are warming the beeswax up in their hands now if you weren't able to heat it in toaster oven.

>>We just talked about some kids who tried really hard, practiced, and were successful. But what is actually happening in your brain when you practice something? [Take a few answers to gauge what they already know.]

What's inside my brain?: First, let's talk about what your brain is made of. In our brains are about 100 *billion* of these tiny nerve cells called neurons. Can we all say that together? [all together: "Neurons"] Right. These neurons have special parts that other cells in our body don't have that lets neurons talk to each other. We'll talk more about how these look like in a little bit. [on ppt:] This character is Nelson the Neuron. He's going to help show us all the super cool things that neurons in our brains do!

Special jobs: All of the neurons in your brain are responsible for going different, special jobs. Can anyone think of what kind of jobs a neuron in your brain might have? [*Prompt:* What kinds of things do our brains help us do?] Right, they help us think, remember things, move, dream, create.... So you can see Nelson and his other friends here ☺

How neurons talk to each other: In order to do their jobs, your neurons send messages to each other throughout your whole brain and other parts of your body—like they might send messages to your muscles to tell them to move. Neurons send messages to each other using special electrical and chemical signals that can travel over long distances in your brain and body.

When I'm first learning: When you're first learning something new—especially something challenging and complicated, you might only have a few weak connections between all of the different neurons in your brain that you need to do this activity. For instance, when you're first learning long division, this can be super hard. However, that doesn't mean you're not smart! It just means that you need more practice so that the connections between your neurons can grow stronger. [connect back to examples the kids had when they were talking about something that was hard for them.]

Good news: So what do you think? Can the connections between your neurons get stronger? [Yes!] How does this happen? [By practicing!] Right! Not only can you see people get better at doing hard things like long division or running a marathon, but when we learn and practice a new task, our brain gets stronger. The connections between our neurons get faster and stronger, and our neurons are able to talk to more and more parts of our brain that can help us do these hard tasks.

[point out Nelson] See how many more connections Nelson can make? Each one of these connects him to another neuron. This process of becoming stronger and growing more connections is called <u>neuroplasticity</u>.

Plastic?: [If no kid brings it up, the **Other researcher** should bring up]:Wait so does that mean my brain is made of plastic?

>> Who can tell me what plastic means? [definitions]. So another definition of the word plastic is something that can be easily changed or molded. So when we say our brains are plastic, it means they change as we learn. So let's recap: When we learn and <u>[practice]</u> new things, we make the <u>[connections]</u> between our <u>[neurons]</u> stronger and make <u>[new connections]</u> between neurons that couldn't talk to each other before. Right now, you are all making new connections between your neurons, since you're learning all this information about how your brain works. [high five!]

Remember: Don't give up if something is hard at first—it's not your fault! Your neurons haven't gotten to make new and strong connections yet! Keep at it and, as your brain changes, you'll get better! Neurons + practice + plastic = Neuroplasticity!

Make a neuron	-beeswax -neuron plushy	10

>> Directions: So now that you know what a neurons does, let's make neurons out of beeswax. This [plushy] is what a neuron looks like. Notice the branches around the body, and then this one long branch.

As participants make their neurons, you can engage them in some light conversation:

- *Brain questions:* Do you have any questions about the brain?
    - Did you know there are two kinds of neurons? Some are gray and some are white
        - Some neurons are called "white" because they have a little roll of fat around their main branch. These fat rolls are called myelin. They make the neuron able to talk faster and they make the neuron look white!
        - White matter is usually on the outside of the brain, gray is usually on the inside.
- *General growth-mindset questions:* What do you want your brain to be better at?
    - What kind of things do you think you can practice to make your neurons better at doing that?
- *Intervention questions:* Do you have any questions about what people have done to "train their brain"?

>> Summary points: What did we talk about today? *Ask kids for these points or remind them.*

- Our brains are made of <u>neurons</u>.
- When we <u>practice</u>, these neurons get stronger, faster, and talk to more neurons.
- Our brains can <u>change</u>! (Neuroplasticity)

>>Homework: Sometimes when we try really hard, we run into problems. Between now and next week, try to notice some of the problems you run into when you try. What do you feel? What do you do about it? You can tell us about it next time.

Motivation Lesson 3 — Persistence and Frustration

OVERVIEW

Icebreaker: Something important to them & what job they want in the future.

Core message: Sometimes things are hard but if they're worthwhile, we should persevere. That can be frustrating sometimes; instead of giving up, let's try some strategies!

Activity: Lindsay's video, Tissue paper bugs.

Questions/ Conversation starters:

- When discussing jobs, use path metaphor verbiage
- What strategies do you have when you get frustrated or angry with someone?
    - Distancing: count to 10 before re-evaluating what you want to say.
    - Distancing: Take yourself out of the scene for a while (relate this to bug activity).
    - Another approach: What else can I do?
    - Draw it out: Where is the problem? What can I do about it?
- When you find yourself working really hard on a school task, it's ok. That just means it's important to you.
    - Use your feelings about working on a school task to tell how important it is for you. If you keep working even when it feels hard, it's probably important to you. Difficult goals are the important ones. Difficult goals means should work harder.
    - Nothing wrong with working hard! Having to work hard at a task means it's important (Elmore et al 2016).
- She mentioned self-esteem a bit; what do you think that is? How is your self-esteem?

Activity	**Supplies**	**Time (min)**
Introductions		<10
Frustration discussion	(-paper/ pencil) (-whiteboard)	10
Tissue bugs	-tissue paper -colored pencils -twisty ties/ shoelaces -scissors -crayons Link with directions: http://bit.ly/2qcmkvk	10
Strategies discussion		10
Lindsay video	-Lindsay video -screen	5

LESSON PLAN

Introduction		<10

Continue to establish rapport with the students and make them comfortable. Ask them how things are with school and their hobbies. When starting:

>> Welcome back! Today, let's introduce ourselves with what kind of job you want to be. Then, we're going to go back around and introduce the person to our left. So I'm Hello Kitty and I want to be a novelist.

Continue around the circle, going in the direction of the other researcher. Then have everyone introduce the person to their left.

>> Recap: So when I learned that Dear Daniel wanted to be an animal photographer, what happened in my brain?

Participants might mention: Your neurons made a connection, you learned something new.

So as Daniel and I keep talking about photos and animals and where he might take those pictures or display them, what's happening?

Responses: You're practicing this new information. The neurons connecting Daniel with photography and animals get stronger and you are more likely to associate him with animal photography.

Frustration discussion	-paper/ pencil (-whiteboard)	10

It might be useful to have the assistant researcher take notes on what the kids bring up so you can refer back to it later.

>> Trying hard and importance: When I tried to learn to run, it was really hard at first and I was really tried and frustrated with myself. But then I realized that becoming fit was really important to me and tried again.

As I strive to be a professor, sometimes I run into obstacles. There are a lot of papers to write, the participants in my studies sometimes don't do what I ask them to, and some people even bring me down. But becoming a professor is important, and that's why I keep trying.

(Talk about persisting and future goals in terms of a path metaphor): In both of these, I was on a journey to get better and accomplish something important. There might be obstacles in my path, but I need to keep moving if I want to reach my goal.

Can you think of a time where you had to accomplish something that was important? *[Discuss possible obstacles on the route to becoming what they want to do.]*

Tissue Bugs	-tissue paper -colored pencils -twisty ties -scissors	15-20

>>Directions: Let's take a little break now. Today we're going to make little tissue bugs. Let's start by coloring the tissue paper. When you're finished coloring, you're going to crinkle it into a little bug and then I'll help you make its thorax with a twisty tie.

Strategies discussion		10

>>Strategies:

- What strategies do you have when you get frustrated or angry with someone?
  - Distancing: count to 10 before re-evaluating what you want to say.
  - Distancing: Take yourself out of the scene for a while. Imagine you're a fly, like the one you are making, and you're just sitting over there by the window, watching it all happen to you. Think about the situation from the fly's perspective before you decide what to do next.
  - Another approach: What else can I do?
  - Draw it out: Where is the problem? What can I do about it?

- When you find yourself working really hard on a school task, it's ok. That just means it's important to you.
  - Use your feelings about working on a school task to tell how important it is for you. If you keep working even when it feels hard, it's probably important to you. Difficult goals are the important ones. Difficult goals means should work harder.
  - Nothing wrong with working hard! Having to work hard at a task means it's important.

Lindsay video	https://youtu.be/t6UjKITAL3s	5

Generally talk about the video:

- What did you think of the video?

- Lindsay talked about feeling frustrated and down about herself. Do you feel like that sometimes?
- She mentioned self-esteem a bit; what do you think that is? How is your self-esteem?

It'll be hard to color with the color pencils on tissue paper: "But just because it's harder to color with the colored pencil doesn't mean we should just give up! Otherwise our bugs would be colorless and that's lame :C So even though it's a little frustrating, we can still stick to it and color patiently so it doesn't rip." —> Talk about ways to distance and talk about frustration—> Bring out crayons. "Sometimes, part of persevering can be finding another angle and another way to look at a problem and solve it." (because crayons will not rip the tissue paper)

>> Summary points: What did we talk about today? *Ask kids for these points or remind them.*

- Things that are hard are usually important to us! We should persevere in important things.
- We went over a few strategies for when we get frustrated or emotional. It's important to take time to go over things calmly.

>>Homework: Like we found out with the little crayon prank, sometimes part of persevering can be finding another way to look at a problem. Before next time, I want you to try a new strategy with a problem.

Motivation Lesson 4 — Creativity

OVERVIEW

Icebreaker: Favorite animal.

Core message: People who struggle with ADHD sometimes are more creative too! So when you find yourself struggling with something, try to approach it from a different way!

Activity: Famous people with ADHD, Create an alien animal.

Questions:

- What strategies do you have when you get stuck on a problem?
- What's another way we can think about this?
- What kind of animal did you make?
  - Where does it live?
  - What does it eat/ how does it get food?
  - How does it avoid being eaten?
- Looking something up can help you understand something better. It helps you be smarter about something.

Ending thought: When we run into challenges, it can be frustrating, but we can persevere through it, and our neurons will grow. Don't give up! Keep trying and look for other ways to solve the problem or make things better. You're smart/creative and can think outside the box, so do that!

Activity	**Supplies**	**Time (min)**
Introductions		5
Create an Animal	-Create and animal sheet: http://bit.ly/2eT0tQM -pencils -scissors -glue -animal books for reference	15
Famous ADHD slideshow	-famous ADHD people slideshow -screen	15
Consolidate ideas		10

LESSON PLAN

Introduction		<10

Greet students. Ask how things are going with their school and hobbies. Ask if they tried a new strategy with a problem or how they demonstrated perseverance since the last meeting.

>> Welcome back! I know we all know each other by now, but let's introduce ourselves just for fun. Today let's share our favorite animal. So I'm Hello Kitty and my favorite animal is a cat. I have a Persian cat called Charmmy Kitty. (I also have a hamster called Sugar.)

Continue around the circle.

Can anyone remind me what we talked about last time?

Responses: Perseverance. How to overcome frustration. [Maybe share some ideas of what they tried.]

Create an Animal	-Create and animal sheet -pencils -scissors -glue -animal books for reference	15

>>Directions: Now that we've talked about our favorite animals, let's make our own! In this activity, you are going to be a zoologist who has just discovered a new type of animal. As every good scientist does, you will document your exciting finding. Design a fact sheet highlighting your new aminal discovery. Remember to think about the name of your animal, what it needs to survive, how it gets these, and where it lives.

As they draw, comment on things they may need to consider. Then as people are finishing, go around presenting the animals. Set a strong example with the researcher animals and remember to cover things like below:

- What kind of animal did you make?
    - Where does it live?
    - What does it eat/ how does it get food?
    - How does it avoid being eaten?

- How does it move?
- How big or small is it?
- How does it interact with its environment? With other members of its kind?
- When does it sleep?

- If you need some ideas to get you started, feel free to flip through some of the books.
    - Looking something up can help you understand something better. It helps you be smarter about something.
    - Learning about something doesn't make you less creative or original; treat it as a tool to help you be even better. "Learning your craft"
- [Refer to creativity as the creation of the animals, not only on the artistic drawing ability.]

Take pictures of the work.

Famous ADHD slideshow	-famous ADHD people slideshow: http://bit.ly/2p8i8LU -screen	15

>>All of these were very creative ideas! I particularly liked the thoughts everyone had about how their animals were. Remember to mark them on your diagram later!

We know from science that many people with ADHD are often exceptionally creative. Do you know anyone else that has ADHD?

Some people might mention celebrities or family members.

Just for fun we compiled a list of some famous creative people who also have ADHD.

Go through the powerpoint. Mention a few of the things they accomplished.

Consolidate Ideas	Final handout	10

We've talked about a lot of things in these last two weeks. Next time you'll be answering a few survey questions like last time and playing the games the other researchers had you doing. But before you leave, let's think of all the things we've talked about.

>>Summary:

1. We can get better at the things we care about by working hard.
2. When we work hard on something, our brains are connecting neurons to make connections and get stronger and better.
3. We need to persevere in important things. Sometimes this is frustrating but we can calm down to think.
4. Part of persevering can be asking for help or thinking of a new strategy. We're good at being creative so let's think of creative strategies! ☺

APPENDIX V

Lesson Plans for the Control (Study Skills) Group

Study Skills Lesson 1 — Studying environment

OVERVIEW

Icebreaker: Grade, favorite subject in school, where they study.

Core message: Internal/ External distractors, Distractions/ multitasking isn't conducive to studying or working.

Activity: Draw their study environment, interview their peers.

Conversation starters:

- What distractors do you have?
- Music while studying:
  - Everyone's different and you need to find what works for you. Listen to your parents' suggestions.
  - What do your parents say?/ Talk to your parents about options (ambient sounds/ lyricless songs)
- How do we use [math]? -- Answer at face value. Avoid talking about growth mindset.
- Extrinsic rewards.
  - Talk to your parents about a reward if you finish your homework.
- For tiger mom/ busy schedule kids:
  - Block out time.
  - Pomodoro (e.g. 10 min work, 2 min break)
- Even if you need a study break every minute, you can interleave your studying and switch subjects. Experiment to see what works for you.

Transition out/ Homework: Try to use some of the solutions you came up with on your study sheet.

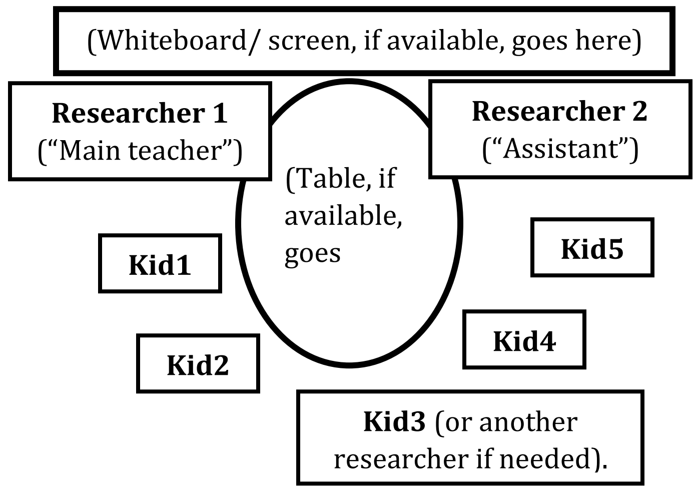
Activity	**Supplies**	**Time (min)**
Introductions		10
Draw study environment	-blank paper -pencils	10
Distractors interview	-distractors interview sheet -pencils	10
Study Space Plan	-distractors interview	10
Rock-Paper-Scissors		5

LESSON PLAN

Introductions		10

Greet parents as they come and bring the child into the room. Introduce your name and try to talk to them and make them comfortable as people arrive.

Have students sitting in a rough circle:



After everyone has had a chance to arrive and talk a little bit:

>> Hello everyone! So to start out, we're all going to introduce ourselves . Let's say your ***name, grade in school, & favorite school subject.*** I'll start. My name is Hello Kitty, my favorite school subject was language arts, and I'm in my third year of graduate school—can anyone guess what grade that is?

Participants: 5th! 10th! 12th, etc etc etc.

(Someone will guess it or you just can walk them through it like: Well when you graduate high school you're in 12th grade. Plus 4 years of college, then another 3 years… (19!) That's right, 19th grade. Can you imagine being in school that long?)

I've been in school so long because my favorite subject is [psychology] and I wanted to keep studying it!

*[**The other researcher** goes, then continue around the circle. Feel free to make short comments about their hobbies, particularly to build rapport.]* (Oh I like reading too! What are you reading now?/ What's your favorite sport? What belt are you in martial arts? What's wingchun? That sounds cool, let's talk about that more later!)

Draw study environment	-blank paper -pencils	10

>>Directions: We just talked about where we study but we didn't really talk much about it yet. So now let's draw out where we study. You're only going to have about 5 minutes to do this. Think of how you might best show how you do it.

While they're drawing, have one researcher studiously draw with them; have the other one (others if there are 3 researchers) do distracting things. Ideas for what to do:

- Whistle/ hum
- Open/ close doors and windows.
- Shuffle papers/ pencils.
- Play a song on your phone or watch a video.
- Tap/ move chairs
- Sigh audibly

After the first few things, pretend to notice them glancing at you: Oh sorry, am I distracting you?

They will catch on and laugh. So was what we were doing distracting while you were trying to draw? Today we're going to talk about things that distract us while we're trying to do something like homework or studying.

Tell me about your work space. *Go around and share work space pictures/description.*

Distractors interview	-distractors interview sheet -pencils	10

>>Define: While you were drawing, we were being distracting. Specifically, we were external distractors. Does anyone want to guess what that means? [External is outside of something?] Right, these are things that are outside of you. Can anyone think of any examples? [Shuffling papers, typing loudly, talking on the phone, annoying siblings, etc.]

What do you think the other kind of distractor is? [Internal!] Right. Any ideas of what this looks like? [Being hungry/ tired, thinking of other things, feelings]

Let's get to know each other a bit with this interview sheet. Go back and forth and <u>ask what kind of things distract you</u> when you're trying to work in your workspace. With your partner, determine if this is an external or internal distractor and try to think of some things you could do about it. Try to come up with as many as you can in 5 minutes!

Pair up students and have one researcher with each group.

- What distractors do you have?
- External:
    - My siblings bother me
        - Ask them to be quiet
        - Schedule time to play later
        - Ask a parent for help controlling them
    - People thinking out loud/ talking.
        - Ask them to be quieter
    - Outside noises

        - Close doors/ windows
        - If it's temporary, maybe use this time to take a short break or do something else? (e.g. I live next to train tracks. When a train goes by, I can't even hear myself unless I scream and sometimes my room shakes. I usually use this as a chance to go refill my snacks, get a drink and reorganize my desk.)
    - Clutter on desk/ not having the needed supplies.
        - Put away your non-studying materials. Turn off/ close the computer while you're working, unless you need it to study.
        - Clean off your workspace when you stop every night.
        - Have a pencil box with all the things you need and keep it near your work place
            - Pencils/ erasers
            - Pens/ white out
            - Highlighters
            - Paper—scratch paper, lined paper.
            - Postit notes/ flashcards
            - Paper clips/ tape/ glue

- Internal:
    - Hungry
        - (Healthy) snack breaks to reward you for working.
        - Water usually works as well.
    - Tired
        - Take a quick walk or stretch break.
        - Snack
        - Make sure you get enough sleep at night.
        - Shower
    - Thinking about other things
        - Take a short break. Refresh. Come back to the table and think only about your homework.
        - Write down these distracting things on a post-it note or notepad to think about later. (If you think about it more than once, make a mark to show that you were really distracted; this is a distraction log. It's supposed to help us be aware of what is occupying our attention.)
        - Make a list of to-dos. Order them in terms of priority and then go down the list. (We will talk about this more in the 4th session)
    - Feelings (being too excited, happy, sad, disappointed, etc…)
        - Talk to someone or write it down (journal), then come back to it later.
        - Turn it into motivation to do your work

>>Share out: Let's share out a few of our ideas. Let's have each group talk about one external and one internal distractor.

Study Space Plan		10

>>Making changes: Now that we've had a chance to talk about our study environment and some of our distractors, go ahead and fill out the "My Study Plan" section on the right side of the worksheet with your partner.

- What would you want to change about your study environment?
- What are you going to do about your distractors?

Rock-Paper-Scissors		5

>>Directions: Does everyone know how to play rock-paper scissors? *[have two kids demonstrate]*

And does everyone know how to play a thumb war? *[have kids demonstrate]*

What if you were to try both at the same time? It'll be hard, wouldn't it? *[They might think it isn't; have them try it out wither way and they'll realize it's trickier than they thought.]*

This is multitasking. It's harder than you think, isn't it? Think of multitasking as another external distractor. If you're working on something and you start something else, like another homework assignment or talking to your friend, that thing is a kind of external distractor from your original task! And because it's a distractor, that means you aren't being as effective and productive with your time as you could be.

>>Transition: Don't forget to try some of your solutions when you get home; I'll ask you about them next time!

Study Skills Lesson 2 — Note Taking

OVERVIEW

Icebreaker: Job you want. Did they try any of the strategies since last time?

Core message: Taking meaningful notes helps us remember and review what we have learned.

Activity: Scavenger hunt, Short story.

Questions:

- How to take notes: (Can you think of situations where one kind of note-taking might be helpful?)
  - Do you write everything down word-for-word or only the key words?
  - Drawing pictures/ diagrams/ mindmaps.
  - outline/ hierarchy.
  - Paragraph form.
- Why do you take notes?
  - Helps you remember things
  - Quick summaries of a long lesson or book
  - To capture the important parts of the lesson so you can go over it quicker later.
  - To clarify things you had questions about.
  - In case a friend couldn't attend class.
- How might you use notes in your future ideal career?
- What to take notes on?
  - Paper is preferred. If you have a notebook, considering sectioning off pages in the notebook/ binder for each subject you have. That way when you go to look for notes for a class, it's in one place.
- Write what we think will be important!
  - Having a lot of notes doesn't help unless we can read it: That means it has to be organized and concise.

Transition/ Homework: Take notes in a class (or on a book/ movie and bring them to class. Or just talk about how you changed your note taking.) So now you have a bunch of notes! But what can you do with them? That's what we'll talk about next time.

Activity	**Supplies**	**Time (min)**
Introductions		10
Scavenger hunt activity	-paper & random prizes	7
Extending to jobs discussion		8
Note taking story	-notetaking & judicial system charts -flow chart	15
Pop quiz	-quiz -notetaking summary sheet	5

LESSON PLAN

Introductions		10

>>Welcome back! Just in case, let's go around with our name and what job you want in the future. So I'm Hello Kitty and I want to be a novelist when I grow up. So I want to write books!

Continue around the circle, going in the direction of the other researcher.

>>Recap: Can anyone remind us about what we were talking about last time?

Participants might mention: Where we study, internal/ external distractors, we did the rock-paper scissors (multitasking).

Right, we talked about our study environment and how to overcome some distractors. Did anyone try one of the solutions we discussed? For example, I talked to my little sister about playing while I was working and she agreed to read quietly until I was finished.

Possible responses and follow up questions:

- I tried to _____ like we talked about.
  - Great!
  - How is it working out for you?
  - Did you run into any problems?
- I tried to ___ but it didn't work.
  - Let's think of another strategy.

Scavenger hunt activity	-paper -random prizes	7

Have paper and pencils in front of them.

>>Reading the lists: So to start out with, we're going to have a little scavenger hunt! I'm going to read two lists, and you'll have to find everything from **ONE** of the lists. Here's the trick: I'm only going to tell you which list you're going to look for ***after*** I read them. I'm only going to read the lists once, so pay attention!

If they don't move, the **Assistant can hint:** You might want to take notes!

These are sample lists; use whatever is available around the room!

List 1	List 2
Bubbles	Blanket
Purple pencil	Red pencil
Blue pen	Shoelaces

Ruler	Notebook
Yellow post-it notes	Slinky

Ok! You have 2 minutes to find everything now! Go!

Assign participants lists to find. After they point out where everything is, point out some of the things they did:

- How did you take notes?
    - Did you write out every word?
    - Did you draw pictures?
- How did you use your notes?
    - Did you use it as a checklist?
    - Did you compare lists to help each other?
    - Once you knew you didn't need one list, did you even look at it?

So it seems like the notes were useful, at least for this activity!

Extending to jobs discussion		8

>> Today's thesis: Today we will be talking about taking notes. You obviously already know how to take some notes, so today we're going to try to build on your note-taking skills and give you new ideas for how you might like to take notes.

>>Why notes?: But first let's talk a bit about why you might want to take notes. Can you think of some ideas?

- Helps you remember things
- Quick summaries of a long lesson or book (Might be useful to bring up Cliff Notes/ Spark Notes for the older kids.)
    - *It might help to talk about how to use Spark Notes things more honestly;* you can use them to <u>supplement</u>, or make better, your learning. But if you don't read the book itself, you miss out on things like:
        - The details of the scene/ passage and the experience of the story.
        - The rhetoric. Especially in AP classes, *how* a writer says something is as important as *what* they are saying.
- To capture the important parts of the lesson so you can go over it quicker later.
- To clarify things you had questions about.
- In case a friend couldn't attend class.
    - But notes are only as useful as the time spent making and reviewing them so you don't want to rely on other people's notes!

>> Notes in Professions: All good reasons. But notes aren't just for school. Earlier I said I wanted to be a novelist. I might take notes about what my characters are like, how I want them to grow, what a scene looks like, the major points in the story, etc. Or if I'm meeting with an editor, I might take notes about what I want to change, or different reactions they had. *[If you have example notes, that could be an extra touch you can bring in to show them that people actually do take notes!]*

Go around in a circle, and help students generate how they might take notes in their future jobs. (E.g. One student wants to be a baker. She'll have to take notes when she's trying out new recipes.)

Note taking story	-judicial system charts -story -flow chart	15

>> Good / Bad notes: There are many good ways to take notes, so you can find the kind that works for you. Some ways are more effective in some cases or other. For example, if I were giving a lecture on the branches of government or something, I might organize the branches as a tree diagram *[Show diagram, explain)*. But if I'm taking notes for a story I might do something different.

[Hand out Notetaking Chart, point out the different note taking methods.] This sheet has a bunch of ways to take notes. Some methods might work better than others in different situations or for different people. For example you can write your notes, or even draw figures or mind maps, use bullet points.

>>Story: So now I'm going to read you a story. *(For younger kids):* The first time you can just listen; the second time go ahead and try taking notes using any of the methods from this handout. *(Older kids can probably just try taking notes.)*

[Have each person take notes a different way as an example. If someone already claimed one]: Oh, but [name] is already using [that method]. Why don't you try another? *(It's ok too to have two people do the same one).*

STORY:

Julian was just an ordinary student in 5th grade. She was just average at school: she went to class and did her homework like everybody else, but she didn't really get it. Anything they learned in class would just leak out of her brain. What she really wanted to do though, was play basketball and the violin. She had tried but she wasn't good at those either.

One day she got a strange ability that just gave her the right answer to any question. If she just concentrated on a single problem, the answer would come to mind. Not just any answer now—the right answer, and how do to it. Suddenly, she was able to get everything right on her tests. She made amazing basketball plays. She played everything right in violin. For homework, she would just need to think about the question and the steps would just appear in her head. It was glorious. She started getting involved in all kinds of things just because she knew she could do it perfectly.

But then she worried that the right-answer ability would suddenly go away, as quickly as it had appeared. She decided she couldn't possibly go back to being bad at everything. Even with her right-answer ability, she couldn't always remember everything. So she started taking notes on the plays she made in basketball and what they learned in class. Sometimes her notes were incomplete. But when she read them again she would remember what she had been doing or what they were learning— or at least remember that she had to read more about it.

She started practicing so she could make even better plays and so that even if she lost her right-answer ability, she could still make a guess based on what she did know.

One day, she really did lose the right-answer ability. She wasn't able to look at a problem and suddenly know its answer. But by then, she had studied enough so that she knew how to solve it—or at least where she could look it up.

[give them some time to take notes and write things]

>> Briefly go over: How did you write your notes? What were some of the pros/cons of methods used.

Notice and bring up these:

- How to take notes:
  - Do you write everything down word-for-word or only the key words?
  - Drawing pictures/ diagrams/ mindmaps.
  - Outline/ Heirarchy, flow.

Pop quiz	-quiz -notetaking summary sheet	5

>>Surprise! We're going to have a pop quiz! But luckily you guys took notes because it's going to be an open note pop quiz. There're one section on the story we talked about and another about the branches of government.

Talk about how notes helped.

Grade once they're done and give them something from the scavenger hunt as a prize.

>>Transition: For next time, take notes for something—a class, a book, something you experienced. We'll ask you how it went next time.

[If there is extra time:] Go through the notes handout in more depth.

Study Skills Lesson 3 — Spacing/ Study Schedule

OVERVIEW

Icebreaker: Favorite animal, what you took notes for since last time and how

Core message: Spacing out and interleaving studying is better for long term memory.

Activity: Mark when they would study and make/ decorate their own study calendar.

Questions/ Conversation starters:

- Using the notes that you brought in, how would you organize your studying for this subject?
- What do you do when studying?
  - Repetition/ Retrieval.
  - Testing
  - Visualizing/ drawing diagrams
  - Study guides
  - Using vocabulary in context
- What kind of strategies do you have for organizing your studying?
  - Cramming
  - Spacing
  - Interleaving
- When do you study?
  - Weeks beforehand (to get ready for it)
  - The day before (in case new material is covered/ to review/ keep it fresh in mind)
  - Multiple sessions
- What if you have multiple tests on the same day?
  - What about weekly spelling tests where you don't know the schedule until the week of?
- What if you have questions while studying?

Transition to next lesson: Pay attention to how you spend your time – are you spacing/ interleaving? What do you spend a lot of time on? What does your schedule look like on a normal day?

Activity	**Supplies**	**Time (min)**
Introductions		10
Study Session		10
Spacing/ Study Schedule	-Calendar sheet -transparency/ plastic cover -dry-erase markers -eraser/ tissue	15
Color your calendar	-blank calendars - color pencils -plastic cover sheets	10

LESSON PLAN

Introductions		10

>> Welcome back! Today let's introduce ourselves with our favorite animal and something we studied since last time. So I'm Hello Kitty and my favorite animal is a cat. I have a Persian cat called Charmmy Kitty. (I also have a hamster called Sugar.) Since last time I haven't studied for a class or anything but been reading about Shakespeare and took a few notes about his early career.

Continue around the circle. As each person mentions what they studied, ask: **Did you take notes for it?** Some possible follow up is included as well.

- Yes
    - Cool! How did you take your notes?
    - Did that seem to work for you?
    - What kind of things did you remember from that experience?
- No
    - That's ok too. Why not?
    - Would you take notes if you could?
    - What kind of things would you want to remember from that experience?

Study Session		10

>> What do you do when you study? Last week we talked about how to take notes and how now we have all these notes and we know when we're going to study. But what do we do when we study?

Go around sharing ideas for what to be doing when studying. Below are some ideas on what students might bring up or what a researcher might bring up

- Repetition/ Retrieval.
    - Spaced repetition
    - Flashcards
        - Making them is part of studying!
        - Digital flashcard apps.
- Testing
    - Making your own test questions.
    - Practice tests
    - Look up practice problems.
- Visualizing/ drawing diagrams
- Study guides
- Using vocabulary in context

If it hasn't already been brought up, make sure to bring up and tell them about interleaving:

>>Interleaving: Scientists have discovered that a useful technique when studying is to switch up what you're working on every so often. This is called interleaving and is not multitasking! The idea is that we might want to study a few things on a given day. When we do, instead of studying one thing for 4 hours straight, we can study one subject for an hour or two, then switch over to another. Interleaving is when you alternate the subjects that you study within a given study session.

Spacing/ Study Schedule	-Calendar sheet -transparency/ plastic cover -dry-erase markers -eraser/ tissue	15

Pass out markers to the kids in different colors. Have a calendar sheet with the current month marked on it. Mark a day in about 2 weeks as "TEST!" and show them.

>>Mark the calendar. So let's say that you have a big test on [the 20th] and today is [the 1st]. Could you mark three times when you would definitely study? Of course if it was a big test you would probably study a lot more, but for now let's just mark 3 times.

***Assistant researcher**:* I'll start. So, just for fun, I'm going to put all my studying on the 19th or maybe 2 on the 19th and one in the morning on the 20th.

Some kids might laugh at this. That's the point. Go around in a circle and let them mark theirs. Go over their choices after and let them explain why:

- So you chose to study [right before], [the day before that] and a week before. Why did you decide on these days?
- You also chose [these days]. Did you have another reason?
- A few days before:
  - Doing practice problems
  - Reviewing notes.
  - Rereading the textbook
  - Gives you time to ask questions and get answers from the teacher or another student.
  - Making study guides.
- Studying right before the day:
  - Just in case
  - Final review
  - To make sure you know everything
- "Studying" a few weeks before:
  - (They might not have the opportunity to do this in elementary school, but you can tell them that in middle and high school they generally have a syllabus (schedule) that tells them what/ when they will be covering in class, the assignment due dates)

- To preview the material that you have to look at
- Knowing when you will be covering certain topics.
- Making sure you have enough time to study on particular days. (e.g. A recital is the night before a big test; better make time a few days before so you have time to practice and so you don't have to cram the night before)

>> Cramming: So [other researcher], I noticed you [and other student?] in particular decided to <u>cram</u> everything on one day, specifically the day right before the test.

Just like interleaving, scientists have discovered that <u>spacing</u> out learning is the most effective. Instead of cramming everything into the day, take time so that you can space out your learning across a few days. So we would want to have a few study sessions a few days before and of course the session right before, just in case.

>>Alternating/ Spacing: In middle/ high school you might have more than one test on a given day though. So let's say you have a big math test on this day [similar to the last one], but you also have an essay due for social studies that day. You also have reading quizzes every Friday. Given this layout, please mark when you would study for each thing?

- This is also your chance to personalize your study plan a little! For example:
  - I read slowly so I'd want to make sure I set aside time every week before Friday to read for the reading quizzes.
  - I tend to get really picky about touching up and finalizing what a project looks like at the end so I want a full day to work on the project at least 2 days before it's due.
  - I'm really good at math so I only would need 2 sessions to study for it.
  - What if I had a swim meet the day before the big test? I would want to get extra sleep for that.
  - I don't want to study on Sundays. That day is for family, community and video games.

Color your calendar	-blank calendars - color pencils -plastic cover sheets	10

>> So now you get a chance to color your own calendar! You can write the dates so you can make it for the month or you can make it a general calendar and change the dates every month. When you're done decorating, we'll give you a plastic sheet so you can mark when you're going to study too. Finish

You can answer questions or trade tips for studying while studying. If it's hard to get a conversation going, a researcher can just offhandedly mention: Hey, so I have a project due a while from now, but I have a bunch of little tests from here until then and I bunch of other things I want to do as well. Since we're talking about studying, how would you guys suggest I study and when?

>> Try putting your study schedule in action or add in your other tests. For next time, pay close attention to what you spend your time on every day. Do you have sports or music or tutoring that you usually go to? Do you do your homework and study the moment you get home? Pay attention over the next few days and let me know when we come back. You can even ask your parents. Don't forget you can take notes if you think you might forget!

Lesson 4 — Time Management/ Prioritizing

OVERVIEW

Icebreaker: Hobbies/ favorite thing to do after school

Core message: When designing a schedule, focus on the important things; prioritize!

Activity: This demonstration/ video. Make a weekly schedule and putting it all together.

Conversation Starters:

- What are some of your big rocks?
  - What do you love doing?
  - Who or what really matters to you?
  - Sometimes big rocks are goals, sometimes they're people.
- How do you spend your time?
  - Does this reflect your priorities and big rocks?
- How do you decide what is important and when do things?
- What strategies do you have when you get stuck on a problem?

Ending thought: Think about your big rocks in life. Whatever your big rock is, make sure you put it in your life first. Don't let everything else get in your way: really concentrate on it when you're doing it, take notes, and make time to study it more.

Activity	**Supplies**	**Time (min)**
Introductions		10
Daily Schedule Sheet	-time management handout	10
Rocks in a Jar demonstration	-jar -big rocks -pebbles -sand -(some paper to put under it all to keep neat)	5
Big Rocks	-Big rocks -Big Rocks sheet -color pencils	15
Consolidate/ Summary		5

LESSON PLAN

Introductions		10

>>Welcome back! I know we all know each other by now, but let's introduce ourselves just for fun. Let's share a hobby or something we like to do or our favorite thing to do once we get home. So I'm Hello Kitty and I like baking. My favorite recipe is apple pie.

Continue around the circle, going in the direction of the other researcher. Then have everyone introduce the person to their left.

Daily Schedule Sheet	-time management handout	10

>> Time management Sheet: Last time we talked about when to study and what to do when we study. But it's one thing to look at a calendar and say "Yeah, I can study all these things" and another to live through that day. So I asked you to pay careful attention to what you spend your time doing every day and when you do these things. So let's take a few minutes and write down on the left side of this sheet what we spend most of our time doing on a normal day.

Just make sure they are filling out the schedule and not getting too hung up on what exactly their doing every minute. We want rough boxes of what they're doing with their time. If they finish early they can do the "Where does the time go" questions on the right.

Go around and share out what each person is spending most of his or her time on:

- How do you decide what to spend most of your time on?
  - Does this reflect what is important to you?
- Where are you losing time/ wasting time?
  - What is actually taking up your time?
  - What do you do when you are procrastinating? Do you actually enjoy doing these things?

When deciding how to plan our time, it's important to think about our priorities are. Can anyone tell me what a <u>priority</u> is? [important things, urgent/ time sensitive things] Great! So we have a little activity about prioritizing:

Rocks in a Jar demonstration	-jar -big rocks -pebbles -sand	5

	-(some paper to put under it all to keep neat)	

>> Demonstration: We have the ability to accomplish anything if we use our time wisely.
[Fill it up with big rocks.] Is this jar full? [Yes]

[Pour in pebbles] Is it full now? [Yes]

[Pour in sand] How about now? [Yes]

Now I want you to recognize that this jar represents your life. The big rocks are the important things-- your health, your family, friends, passions. The pebbles are the other important things—your house, your chores. The sand is everything else, it's just the small stuff. Now if you put the sand in the jar first, you won't have room for the pebbles and the big rocks. The same is true in life – if you spend all your energy and time on the small stuff, you won't have time for all the really important things that matter to you. Pay attention to the things that are critical to your happiness. Set your priorities. Because everything else is just sand.

>> Metaphor: So in this demonstration, the jar was like a symbol or a metaphor for life; does everyone know what a metaphor is? A metaphor is a comparison that isn't literal, but can help you think about something in a different way. So your life isn't actually the jar, but if we think about the jar as the time you have in life, then we can more easily understand the importance of putting in the big rocks first, or making time for important things.

What are some of your big rocks?

- What do you love doing?
- Who or what really matters to you?
- Sometimes big rocks are goals, sometimes they're people.
- Common ones:
  - Family (Partner? Parents? Children?)
  - Health
  - Future career

Big Rocks	-Big rocks -Big Rocks sheet -color pencils	15

>> "Ideal Schedule" worksheet: Now that we've walked through some of our big rocks, let's write them down (taking notes!) Start again on the left, where you can write down about 5 of what are the big rocks in your life, then write down some of the pebbles for comparison. Then on the right, think about what an ideal day would look like for you.

- Did you make time for all of your big rocks?
  - Help them make time – on a daily or weekly scale to make sure they are paying attention to their big rocks and making time for those.

- What are some of your pebbles?
  - Think of the pebbles as some achievements that would be great and amazing to accomplish, but something that if you didn't achieve, you wouldn't be too beat up over.
  - For example: [You should come up with your own…] *Mini likes writing and definitely wants to write a book. It'd be great if everyone loved it and a group of high school kids analyzed it, but it doesn't have to be. So writing stories would be a big rock, but having a high school group analyze it would just be a pebble. And it doesn't matter at all if that happens at Irvine High where I grew up, or some other school. That's just sand in the jar.*
- On School: Kids might say that "School isn't a big rock" for them--
  - Yes, but you still want to do well in school; don't let bad grades or whatever get in the way of you accomplishing your big rocks.
  - *Mini has a personal example: My uncle's dream has always been to fly planes. Any kind of plane would do--He just wanted to fly. But his grades weren't great at first and he wasn't allowed into the program at the time. He ended up working, getting a nice career and everything, and 60 years later, after retirement, he went back and is now allowed to pilot a small plane with supervision. Don't let a few bad grades stop you from doing anything else!*
- On a smaller scale, you can think of the jar as your school subjects.
  - What subjects do you particularly enjoy?
  - For older kids: What subjects do you need in order to take the classes you want? (prerequisites)
  - What subjects are hard for you and you have to set aside extra time or get help for?
  - What subjects are easy for you and you don't need to worry about as much?
- What strategies do you have when you get stuck on a problem?

Consolidate/ Summary		5

>>Summary:

Go over everything they learned throughout the intervention:

1. The environment we study in is important – minimize internal and external distractors.
2. Take notes of important things or things you want to remember. Notes are there to organize your thoughts.

3. Space out and interleave your studying with other subjects. During this time, review your notes and make study guides.
4. Prioritize things in your life so you have time to do what you enjoy and what will help you enjoy your future.