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### Title

Mixed martial arts as a means to improve social communication and executive functioning in children with Autism Spectrum Disorder

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### Author

Phung, Janice Ngoc

### Publication Date

2017

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA,  
IRVINE

Mixed martial arts as a means to improve social communication and executive functioning in  
children with Autism Spectrum Disorder

DISSERTATION

submitted in partial satisfaction of the requirements  
for the degree of

DOCTOR OF PHILOSOPHY

in Psychology and Social Behavior

by

Janice N. Phung

Dissertation Committee:  
Professor Wendy A. Goldberg, Chair  
Professor Jodi Quas  
Professor Yuqing Guo

2017



## **Dedication**

For

my mom and dad

in recognition of your love, sacrifices, and endless support

To

my partner in training and in life

for believing in me even when I did not believe in myself

To

the autism community

for teaching me that different is not less

Finally,

in sweet memory of

Chairman Meow

for watching over me and for your eternal love

“Be water, my friend.”

-Bruce Lee

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## Acknowledgments

I would like to express the deepest appreciation to my advisor and committee chair, Dr. Wendy Goldberg, who has taken me under her wing and nurtured my growth as a writer, researcher, and mentor. I could always count on Dr. Goldberg to offer insightful solutions to challenges and to give unconditional encouragement. She is the model mentor, leading by example with grace, and always encouraging her students to follow their own paths. Without her guidance and support, I would not be the scholar that I am today, and for that I am extremely thankful.

I would also like to thank the members of my committee, Dr. Jodi Quas and Dr. Yuqing Guo, for their excellent feedback on my final project. I am also appreciative of Dr. Joanne Prause and Dr. Stephanie Reich for their insightful comments on the initial development of my dissertation project. In addition, I would like to extend my gratitude to Dr. Amy Dent, who guided me in the statistical analyses of the final project. Dr. Ray Novaco also deserves recognition. His expertise as both a martial artist and a researcher helped me think broadly about my project, and his friendship helped me tap into a resiliency that I never knew that I had.

I am indebted to the many undergraduate research assistants over the years. Without their dedication to helping with participant recruitment, data collection, and the implementation of the intervention, this project would not have been possible. I would also like to thank the families who participated in my research study, not only for their time and commitment, but for allowing me the opportunity to get to know their wonderful children.

Financial support from the School of Ecology Dean's office, UCI Chancellor's Club Fund, and Paul and Frances Dickman Fund made the completion of this work possible.

The implementation and success of this project would also not have been possible were it not for OC Kickboxing & Mixed Martial Arts (OCKMMA). Each week, OCKMMA opened its doors to welcome the families with autism and gave them a place to belong. I would like to thank owner, Robert Freeman, for funding the intervention class. His continued support of the research and program, combined with his commitment to giving back to the community, is truly inspirational. Head Instructor, Daniel Sullivan, has been personally invested in the outcomes of the children, and deserves my thanks for his enthusiasm towards the project. I would also like to thank Senior Instructor and Program Manager, Dennis Hall, for his guidance in developing the program in its initial stages. My humble gratitude also goes to the head coach of the All Stars MMA program, Felipe Munoz, for volunteering to teach the class each week. Never have I seen a coach so devoted to helping his students succeed. I am thankful for his enthusiasm and dedication to each child's progress. He is adored by all his students and is an exceptional role model both on and off the mat. Finally, I would like to extend my thanks to the peer buddies. Although they are just children themselves, they have demonstrated exceptional maturity, compassion, and empathy. I am excited to see the kinds of leaders that they grow up to be.

My time in graduate school would have been incomplete if not for the amazing friends that I have made along the way. My experience would not have been the same without my labbie, Valentina Valentovich, who shared in my misery during countless hours toiling away in the lab. Our work-dates were definitely more fun with her by my side. Homies help homies, always. My incredibly talented friend, Joe Kay, is good at everything that he does. Among those many talents is the ability to be an incredibly supportive friend who I could always rely on, and who always understood and appreciated my Simpsons references. Alisa Apgar has been an endless source of comfort, joy, and humor; I am grateful for always having someone to make me

laugh when I am stressed, and to send me links to cat videos when I need to take a break. Finally, my time at UCI would not have been complete without the friendship of my amazingly talented friend, Cait Cavanagh. In all her fierceness, Cait has not only been my strongest advocate, but more importantly, taught me how to advocate for myself. Without her, I never would have believed that I could accomplish all the things that I have thus far, and I certainly would not have all the cats that she convinced me to adopt.

Even though I have been living in Irvine, I have received tremendous support from friends from home, who have reminded me that life in graduate school is only temporary. In particular, I am grateful for my best friend since childhood, Kelly Vu, for her loving care packages that seemed to arrive just when I needed them, and for her words of encouragement to get me through the week. During my time in graduate school, she has been a source of humor that was only a phone call away, and I could always count on her to know my thoughts before I even say them. The miles are no match for our sisterhood. I also owe thanks to my dear friend, Priscilla Martinez, who believed that I could do this from Day 1. From the early days of reviewing my graduate school applications, to our G-chat pep talks that made the endless days in lab go by more quickly, her objective perspective has been a constant source of comfort and validation. She helped me realize my unique worth when I felt like I did not deserve to be in graduate school, and she never let me forget who I am and where I come from. I am thankful to her for keeping me grounded.

Last, but not least, I am grateful for the love and support of my family. PeYe, for being the easiest part of my life when everything else is hard; Chairman Meow, Leo, and Maggie, who stayed up with me on those late working nights and calmed my many panic attacks. I would like to thank my brother, Bang Phung, for his encouragement and for always believing in me. I would also not be here today if not for my mother, Lina Phungnhieu. Every time I went home to Long Beach, I left with a week's worth of pre-cooked meals. Through her thoughtful and tender preparation of home-cooked food, my mother not only filled my belly and energized my mind, she lovingly nourished my soul. I am so lucky to have a mother who loves and supports me with so much care. Finally, I owe my deepest gratitude to my father, Trung Phung. To say that my father is a hard worker is an understatement; he has worked hard every day of his adult life, making sacrifice after sacrifice to give his family a better life. Not only a man of wise words, but a man of action, my father has taught me to be strong, humble, resilient, and courageous. By leading by example, he has taught me to pursue things even if they scare me; we must dare to pursue our dreams and always try our best. Because he dared to dream, I dared to become the first doctor in our family. Without him, there would be no me.

## Curriculum Vitae

JANICE N. PHUNG

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University of California, Irvine  
Department of Psychology & Social Behavior  
School of Social Ecology  
4201 Social & Behavioral Sciences Gateway  
Irvine, CA 92697

Email: [jnphung@uci.edu](mailto:jnphung@uci.edu)

### EDUCATION

University of California, Irvine (UCI), Irvine, CA

Ph.D., 2017, Psychology & Social Behavior (Minor: Affective Sciences)

Dissertation Title: Mixed martial arts as a means to improve social communication and executive functioning in children with Autism Spectrum Disorder.

Chair: Dr. Wendy Goldberg, Ph.D.

M.A., 2013, Social Ecology

Thesis Title: Adult-provided linguistic support and child language comprehension: Examining effects on encoding and generalization across cues at 20 months.

University of California, Los Angeles (UCLA), Los Angeles, CA

B.A., 2009, Psychology (Minor: Applied Developmental Psychology)

### RESEARCH EXPERIENCE

UCI, Department of Psychology & Social Behavior

2013- 2017, Family Lab, *Graduate researcher*

Principal Investigator: Dr. Wendy A. Goldberg, Ph.D.

2013- 2017, Center for Autism Research & Translation, *Graduate researcher*

Principal Investigator: Dr. Jay Gargus, M.D.

2011- 2014, Memory & Development Lab, *Graduate researcher*

Principal Investigator: Dr. Angela F. Lukowski, Ph.D.

2010- 2011, Memory & Development Lab, *Research assistant*

Principal Investigator: Dr. Angela F. Lukowski, Ph.D.

UCLA, Department of Psychology

2008- 2009, Language & Cognitive Development Lab, *Research assistant*  
Principal Investigator: Dr. Catherine M. Sandhofer, Ph.D.

## PUBLICATIONS

**Phung, J. N.**, Abdullah, M. M., & Goldberg, W. A. (revised and resubmitted). Poor sleep quality among adolescents with autism spectrum disorder is associated with depressive symptoms, problem behaviors, and conflicted family relationships. *Focus on Autism and Other Developmental Disabilities*.

**Phung, J.N.**, & Goldberg, W. A. (2017). Poor sleep quality is associated with discordant peer relationships among adolescents with Autism Spectrum Disorder. *Research in Autism Spectrum Disorders*, 34, 10-18.

Lukowski, A.F., **Phung, J. N.**, & Milojevich, H. M. (2015). Language facilitates event memory in early childhood: Child comprehension, adult-provided linguistic support and delayed recall at 16 months. *Memory*, 23, 848-863.

**Phung, J. N.**, Milojevich, H. M., & Lukowski, A.F. (2014). Adult language use and infant comprehension of English: Associations with encoding and generalization across cues at 20 months. *Infant Behavior and Development*, 37, 465-479.

## CONFERENCE PRESENTATIONS

**Phung, J. N.** (2017, December 16). *On and Off the Mat: Teaching martial arts to improve social and cognitive functioning in children with Autism Spectrum Disorder*. Oral presentation given to caregivers, staff, and other stakeholders at OC Kickboxing & Mixed Martial Arts, Irvine, CA.

**Phung, J. N.**, & Goldberg, W. A. (2017, May). *Play ball! Long-term sports participation is associated with more behavioral regulation in children with Autism Spectrum Disorder*. Poster presented at the International Meeting for Autism Research, San Francisco, CA.

**Phung, J. N.**, & Goldberg, W. A. (2017, May). *Poor sleep quality is associated with discordant peer relationships among adolescents with Autism Spectrum Disorder*. Poster presented at the International Meeting for Autism Research, San Francisco, CA.

**Phung, J. N.**, & Goldberg, W. A. (2017, April). *Repetitive behaviors and executive functions: Linking two challenging areas in children with Autism Spectrum Disorder*. Poster presented at the 2017 Society for Research in Child Development Biennial Meeting, Austin, TX.

**Phung, J. N.**, & Goldberg, W. A. (2017, March). *Stimming and cognition: Linking restricted/repetitive behaviors and executive functions in children with Autism Spectrum Disorder (Honorable mention)*. Poster presented at the Social Ecology Poster Session for Masters & Doctoral Students, Irvine, CA.

- Phung, J. N.,** Goldberg, W. A., & Srinivasan, R. (2016, November). *Brain/clinical trials outcomes: Connections between autism symptom severity, sleep quality, and EEG*. Oral presentation given at the Annual Research Symposium Center for Autism Research and Translation: UCI Applied Innovations, Irvine, CA.
- Phung, J. N.** (2016, April). *MMA & ASD: A Mixed Martial Arts approach to improving social and cognitive functioning in children with Autism Spectrum Disorder*. Oral presentation given at UCI Associated Graduate Students Research Symposium, Irvine, CA.
- Phung, J. N.,** Abdullah, M. M., & Goldberg, W. A. (2016, March). *Examining sleep quality in adolescents with Autism Spectrum Disorder: Correlates with individual well-being and parent-child relationship quality*. Poster presented at the Social Ecology Poster Session for Masters & Doctoral Students, Irvine, CA.
- Phung, J. N.,** Abdullah, M. M., Custodio, E., & Goldberg, W. A. (2015, May). *A multi-method approach to examining correlates of sleep quality, individual well-being, and mother-child relationship quality in adolescents with Autism Spectrum Disorder*. Poster presented at the International Meeting for Autism Research, Salt Lake City, UT.
- Phung, J. N.,** Abdullah, M. M., & Goldberg, W. A. (2015, April). *Sleep quality and well-being in adolescents with Autism Spectrum Disorder*. Invited oral presentation given at Psychology & Social Behavior Departmental Colloquium, Irvine, CA.
- Phung, J. N.,** & Lukowski, A. F. (2015, March). *Adult language use and recall memory in preverbal children*. Oral presentation given at the 2015 Society for Research in Child Development Biennial Meeting, Philadelphia, PA.
- Phung, J. N.,** & Goldberg, W. A. (2014, May). *Sleep quality and daytime functioning in adolescents and young adults with Autism Spectrum Disorders*. Oral presentation given at the International Meeting for Autism Research, Atlanta, GA.
- Abdullah, M. M., **Phung, J. N.,** & Goldberg, W. A. (2014, May). *Sleep quality among adolescents with ASD in relation to internalizing and externalizing symptoms*. Poster presented at the International Meeting for Autism Research, Atlanta, GA.
- Phung, J. N.,** Goldberg, W. A., Srinivasan, R., Horton, C., Hayes, G. R., & Custodio, E. (2013, November). *Sleep quality and daytime functioning in adolescents with Autism Spectrum Disorders*. Poster presented at the UC Insights Symposium, Newport Beach, CA.
- Phung, J. N.,** & Lukowski, A. F. (2013, October). *Adult supportive language use and child language comprehension: Examining associations with delayed generalization across cues at 20-months*. Poster presented at the Cognitive Development Society Conference, Memphis, TN.
- Phung, J. N.,** Milojevich, H. M., & Lukowski, A. F. (2013, May). *Talking to me might help: The*

*role of adult-provided linguistic support on generalization abilities in 20-month-old children.* Oral presentation given at the Southern California Conference on Cognitive and Language Development, Irvine, CA.

**Phung, J. N.,** Milojevich, H. M., & Lukowski, A. F. (2013, April). *Child language comprehension and linguistic support in an elicited imitation task: Effects on encoding and generalization.* Poster presented at the 2013 Society for Research in Child Development Biennial Meeting, Seattle, WA.

Milojevich, H. M., **Phung, J. N.,** & Lukowski, A. F. (2013, April). *Examining correlates of parent psychological functioning: Contributions of parent and child sleep habits.* Poster presented at the Society for Research on Child Development Conference, Seattle, WA.

**Phung, J. N.,** Milojevich, H. M., & Lukowski, A. F. (2012, May). *Infant sleep patterns and parent opinions about infant sleep habits: Examining relations with temperament in 10-month-olds.* Poster presented at the International Conference on Infant Studies, Minneapolis, MN.

Milojevich, H. M., **Phung, J. N.,** & Lukowski, A. F. (2012, May). *The functional consequences of sleeping like a baby: Examining relations between habitual infant sleep and recall memory in 10-month-olds.* Poster presented at the International Conference on Infant Studies, Minneapolis, MN.

**Phung, J. N.,** Milojevich, H. M., & Lukowski, A. F. (2012, April). *Examining relations between language and recall memory in infancy.* Poster presented at the Southern California Conference on Cognitive and Language Development, San Diego, CA.

**Phung, J. N.,** Morales, J., Vlach, H. A., & Sandhofer, C. (2009, May). *The role of implicit learning and experience in children's word learning.* Poster presented at the Symposium on Cognitive and Language Development, Los Angeles, CA.

## TEACHING EXPERIENCE

UCI, Department of Psychology & Social Behavior

### ***Instructor of Record***

2017, Summer, Human Sexuality (P118D)

### ***Teaching Assistant Positions***

2017, Winter, Human Development in Cross-Cultural Perspective (P116D)

2017, Winter, Introduction to Psychology (Reader, Online course) (P7A/P9)

2014, Summer, Human Sexuality (P118D)

2013, Summer, Lifespan Developmental Psychology (Online course) (P101)

2013, Winter, Introduction to Psychology (P7A/P9)

2012, Fall, Lifespan Developmental Psychology (Online course) (P101)



### ***Guest Lectures***

- 2017, November 3, “*Words of Wisdom: The Importance of Peer Review*”  
Course: Field Study Writing Seminar
- 2017, February 22, “*Actigraphy and sleep in patients with Autism Spectrum Disorder*”  
Course: Research Seminar in Psychology & Social Behavior
- 2016, March 8, “*Intervention Study for Children with Autism Spectrum Disorder*”  
Course: Research Design
- 2014, September 4, “*Sex for Sale*”  
Course: Human Sexuality
- 2013, December 3, “*Examining the Associations Between Autism and Sleep*”  
Course: Research Design
- 2013, January 28, “*Cognitive Development in Infancy and Adolescence*”  
Course: Introduction to Psychology

UCI, Division of Teaching Excellence and Innovation (formerly the Center for Engaged Instruction)

### ***Pedagogy Workshop***

- 2017, February 13, “*The Art of Writing Better Test Questions*”  
Course: Instructional Development Interactive Workshop Series,  
Co-Facilitator: Christopher A. Bobier

### ***Pedagogical Fellows Program***

- 2015-2016, A competitive program in advanced higher education pedagogy and academic job preparation that involved receiving one full year of training, designing the TA training program, training incoming TAs in the School of Social Ecology, reviewing applications for the 2016-2017 Pedagogical Fellowship applicants, and a monetary award.

Saddleback College, Department of Psychology

### ***Guest Lecture***

- 2014, November 25, “*Developmental research with special populations*” (*invited*)  
Course: Research Methods in Psychology

## **MENTORING & LEADERSHIP EXPERIENCE**

UCI, Graduate Division

### **2016– 2017, DECADE Plus, Graduate Mentor & Leadership Coach**

Served as a graduate student mentor to first year undergraduate Chancellor’s Excellence Scholars; met weekly throughout the academic year to assist first-generation/low-income/underrepresented students in navigating higher education, balancing personal and school life, and pursuing their academic goals

### **2013- 2014, Summer Research Program, Graduate Student Mentor**

Provided feedback to undergraduate students' graduate school application essays; met weekly to discuss ways to improve the personal statement and research proposal essays

2013, Competitive Edge Summer Research Program, **Graduate Peer Mentor**  
Mentored incoming graduate student in transitioning to first year of graduate school; met weekly to discuss student's experiences and challenges

UCI, Department of Psychology & Social Behavior

2016- 2017, PSB Graduate Student Peer Mentor Program, **Peer Mentor**

2011- 2017, **Graduate Student Research Mentor**; conference presentations by undergraduate student mentees:

Nguyen, K., **Phung, J. N.**, & Goldberg, W. A. (2017, May). *Sibling social influences on children with Autism Spectrum Disorder*. Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.

Silva, S., Garcia, A., **Phung, J. N.**, & Goldberg, W. A. (2017, May). *He said, she said: Examining the quality of spontaneous language production of children with Autism Spectrum Disorder during semi-structured social interactions*. Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.

Zhang, S., **Phung, J. N.**, & Goldberg, W. A. (2017, May). *From start to finish: Assessing the fidelity of a mixed martial arts intervention for children with Autism Spectrum Disorder* Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.

Tomimbang, H., Hamid, N., **Phung, J. N.**, & Goldberg, W. A. (2016, May). *Associations between extracurricular sports participation and social and cognitive ability in children with Autism Spectrum Disorder*. Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.

Hamid, N. Balian, O., Lo, A., **Phung, J. N.**, & Goldberg, W. A. (2015, May). *Associations between sleep quality and peer relationships among adolescents with Autism Spectrum Disorder*. Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.

Hamid, N. Balian, O., Lo, A., **Phung, J. N.**, & Goldberg, W. A. (2015, April). *Sleep and peer relationships of adolescents with Autism Spectrum Disorder*. Poster presented at the Western Psychological Association Convention, Las Vegas, NV.

Hardy, P., **Phung, J. N.**, & Lukowski, A. F. (2014, August). *Investigating the relationship between maternal education, child language comprehension/production, and recall memory*. Poster presented at the Graduate Division Summer Research Program Symposium, Irvine, CA.

Behar, J., **Phung, J. N.**, & Lukowski, A. F. (2014, May). *Iron deficiency and cognitive development among 18-month-old Chinese infants*. Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.

- Behar, J., Baek, S., Fatahi, N., **Phung, J. N.**, & Lukowski, A. F. (2014, May). *Examining the effect of adult language on recall memory at 13 months: Does child language comprehension facilitate recall performance?* Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.
- Davia, S., **Phung, J. N.**, Goldberg, W. A., & Guo, Y. (2014, May). *How best to diagnose autism? A comparison of autism diagnostic measures and their associations with behavior.* Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.
- Fatahi, N., Baek, S., Behar, J., **Phung, J. N.**, & Lukowski, A. F. (2014, May). *Adult-provided linguistic support and recall memory at 13 months: Does adult language use facilitate recall in the first year of life?* Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.
- Shen, J., Kuo, A., **Phung, J. N.**, & Lukowski, A. F. (2014, May). *Fear of missing out and social media use: Examining effects on sleep quality during the transition to adulthood.* Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.
- Escobar, J., Rodriguez, C., **Phung, J. N.**, & Lukowski, A. F. (2013, May). *Adult supportive language: Correlations with delayed generalization in toddlers.* Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.
- Liptrap, K. R., Tanaka, A. A., **Phung, J. N.**, & Lukowski, A. F. (2013, May). *Examining the effects of napping on recall memory in university students.* Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.
- Tanaka, A. A., **Phung, J. N.**, & Lukowski, A. F. (2013, May). *Examining the effects of napping on executive functioning in university students.* Talk presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.
- Hurwitz, L. & Tanaka, A., Milojevich, H. M., **Phung, J. N.**, & Lukowski, A. F. (2012, May). *Examining relations between infant sleep habits and executive functioning.* Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.
- Lavery, T. & Lepore, J., **Phung, J. N.**, Milojevich, H. M., & Lukowski, A. F. (2012, May). *Examining relations between language and generalization in infancy.* Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.
- Ling, S. & Ohana, M., Milojevich, H. M., **Phung, J. N.**, & Lukowski, A. F. (2012, May). *Examining relations among infant sleep, infant temperament, and parent mental health.* Poster presented at the Undergraduate Research Opportunities Program Conference, Irvine, CA.

## AWARDS & HONORS

2017, Social Ecology Dean's Dissertation Writing Fellowship (competitive/\$12,088)

2017, Psychology & Social Behavior Graduate Student Award: Dedicated to Community Service

2017, Social Ecology Dissertation Data Collection stipend (competitive/\$1000)

2017, Chancellor's Club Fund for Excellence Fellowship (competitive/\$6000)

A competitive award intended to recognize and reward academically superior doctoral students who exhibit outstanding promise as scholars, researchers, and public leaders.

2016, Paul and Frances Dickman Graduate Student Research Award (competitive/\$1500)

A competitive award in the School of Social Ecology that is awarded based on the graduate student's exceptional academic performance and service to the community.

2015- 2016, Pedagogical Fellows Program Fellowship (competitive/\$2000)

2014- 2017, Social Ecology Graduate Student Mentoring Award (\$200)

2014- 2015, UCI Faculty Mentor Program travel stipend (competitive/\$500)

2014- 2015, UCI Faculty Mentor Program Fellowship (competitive/\$41,974)

A competitive fellowship designed to increase the number of students who successfully complete their degree program and acquire a faculty appointment. Fellows and their faculty mentors develop a "mentoring plan" to guide progress throughout the year. During the award year, fellows are expected to engage in rigorous research, make progress towards their degree, and submit quarterly progress reports, all under the direction of their faculty mentor.

2014, UCI Associated Graduate Students travel award (competitive/\$400)

2014, International Meeting for Autism Research Diversity award (competitive/\$1000)

2013, Cognitive Development Society Meetings travel award (competitive/\$500)

2011- 2012, UCI Graduate Opportunity Fellowship (competitive/\$35,016)

An award that provides financial support for first year doctoral students of diverse backgrounds who have experienced disadvantages in previous educational experiences.

## **SPECIAL SKILLS & PROFESSIONAL DEVELOPMENT**

### *Professional Development*

UCI, Division of Teaching Excellence and Innovation (formerly the Center for Engaged Instruction)

2015- 2016, Advanced Pedagogy and Academic Job Preparation  
2015, August, TA Training Pre-Service

UCI, Graduate Division

2016, DECADE Plus Training Program  
2014, Mentoring Excellence Program (Certificate of completion)

*Specialized Training*

Autism Diagnostic Observation Schedule (ADOS-2)  
Trained by: Dr. Stephen Kanne, Ph.D.

Thompson Center for Autism and Neurodevelopmental Disorders  
University of Missouri, Columbia, MO  
2016 March 17, achieved Research Reliability  
2014 July 26-28, Research Training Course

Chapman Ability Project  
Chapman University, Orange, CA  
2013 September 25-26, Clinical Training Course

Wechsler Abbreviated Scale of Intelligence - Second Edition (WASI-II)  
2016, February, trained by: Dr. Lisa Tully, Ph.D.

Mullen Scales of Early Learning – Clinical Assessment  
2016, February, trained by: Dr. Lisa Tully, Ph.D.

*Clinical & Field Work*

2009- 2011, **Developmental interventionist**  
Pasadena Child Development Associates, Inc., Pasadena, CA  
Director: Dr. Diane Cullinane, MD.

2007- 2009, **Applied Developmental Psychology intern**  
Megan E. Daly Infant Development Program, Los Angeles, CA  
Director: Dr. Helen M. Davis, Ph.D.

**SERVICE**

UCI, Department of Psychology & Social Behavior

2017, **Graduate Student Awards Committee**

2016- 2017, **Director of Communications**  
Served as the liaison for faculty-student relations to address issues related to diversity and department climate/environment; aim was to resolve tensions and to allow students to thrive in an inclusive department

2016- 2017, PSB Graduate Student Peer Mentor Program, **Coordinator**

Developed and organized a departmental peer mentoring program by matching senior student mentors with first-year graduate student mentees and facilitating peer-mentoring relations

UCI, Graduate Division

2017, DECADE Plus Interview Committee, **Committee member**

Served on interview committee for DECADE Plus leadership coach applicants for the 2017-2018 academic year

2016, September 16, Campus-wide Graduate Welcome and Orientation, **Panelist**

Served on the graduate panel for workshop “Embracing your new graduate life”

2011- 2016, Diverse Educational Community and Doctoral Experience (DECADE)

DECADE is a graduate student-led organization that focuses on increasing the number of women and underrepresented minorities in higher education by providing access to resources such as professional development workshops, mentorship, and networking opportunities.

2016, **Campus Coordination Committee**

2011- 2013, Social Ecology School-based group, **Student Representative**

2013, July 17, TriO Program, **Graduate Student Panelist**

Served on the graduate panel for workshop “Preparing for graduate school”

2013, February 19, Campus Honors Program, **Graduate student panelist**

Served on the graduate panel for workshop “Applying to graduate school”

UCI, Division of Teaching Excellence and Innovation (formerly the Center for Engaged Instruction)

Teaching Assistant Professional Development Program

2016- 2017, **Senior Pedagogical Fellow**

Mentored Pedagogical Fellows to lead 1.5-day long series of TA training workshops for incoming Social Ecology graduate students

2015-2016, **Pedagogical Fellow**

Led 1.5 daylong series of TA training workshops for incoming Social Ecology graduate students

Assistant Directors Search Committee

2016, **Search Committee Member**

Served on search committee for Assistant Director positions (Assistant Director for TA Instructional Development and Assistant Director for Faculty Instructional Development)

#### Peer Review

2015- 2016, **Editorial board member**, *TransScripts: Design in Humanistic Inquiry*.

2016, January, **Ad Hoc Reviewer**, *Autism: International Journal of Research and Practice*.

#### Conference Volunteer

2013, November 18, Cognitive Development Society Conference, **Student Volunteer**  
Volunteered at the registration table at the Cognitive Development Society Conference in Memphis, TN

2013, May 4, SoCal Conference, **Conference Co-coordinator**  
Planned and coordinated annual SoCal Conference on Cognitive and Language Development, hosted by Sarnecka Cognitive Development Lab and Lukowski Memory & Development Lab in Irvine, CA

2013, April 27, SoCal Forum for Diversity in Graduate Education, **Recruiter**  
Discussed the importance of diversity and recruited prospective graduate students at the Southern California Forum for Diversity in Graduate Education, Irvine, CA

#### Community

2016, March 9, St. Joachim School Science Fair, **Science Fair Judge**  
Judged children's projects at the annual science fair by scoring rubrics on 75+ projects, in Costa Mesa, CA

2016, January 11 & 2015, January 12, UCI Anteaters for Autism, **Panelist**  
Served on a panel of autism professionals for workshop "*A Panel about Autism*"

2014- 2016, OC Kickboxing and Mixed Martial Arts, **Developmental consultant**  
Collaborated with program coordinators to develop curriculum for "parent-and-me" classes; facilitated sensitivity training to help employees better interact with children with developmental disabilities, in Irvine, CA

2013- 2015, Letters to a Pre-Scientist program, **Scientist Pen Pal**  
Exchanged postal letters with school-aged children during the academic year; discussed science concepts covered in the classroom and offered a more personal view of the life of a scientist

## **PROFESSIONAL MEMBERSHIPS & AFFILIATIONS**

UC Irvine Diverse Educational Community and Doctoral Experience (DECADE)  
International Society for Autism Research  
Society for Research in Child Development  
Vietnamese Scholars Network at UC Irvine  
American Psychological Association  
Psi Chi: The International Honor Society in Psychology



## **Abstract of the Dissertation**

Mixed martial arts as a means to improve social communication and executive functioning in children with Autism Spectrum Disorder

By

Janice N. Phung

Doctor of Philosophy in Psychology and Social Behavior

University of California, Irvine, 2017

Professor Wendy A. Goldberg, Chair

Autism spectrum disorder (ASD) is a pervasive neurodevelopmental disorder characterized by numerous deficits including social dysfunction and difficulties with tasks that require the use of executive functions (EFs). Social and executive deficits disrupt daily functioning among many individuals with ASD. The goal of the present study was to evaluate the effectiveness of a martial arts intervention in reducing social dysfunctions, and improving social skills and EFs in children with ASD. School-aged children ( $M_{age} = 9.34$  years; 82.4% boys) with a clinical diagnosis of ASD were recruited for the present study. Clinical diagnoses were confirmed by administration of the ADOS-2; all children met criteria for ASD. Intellectual functioning was low average. Children were randomly assigned into one of two groups: the mixed martial arts (MMA) intervention group and the waitlist control (WLC) group. The MMA intervention featured activities targeted to train specific domains of EFs, namely behavioral inhibition, working memory, and cognitive flexibility. The MMA intervention also included typically-developing peer buddies who helped facilitate the social skills component of the study by modeling appropriate behavior and providing opportunities for social engagement during the MMA class sessions. Comprehensive assessments were conducted before and after the

intervention. The MMA group was scheduled to receive a 26-class session (approximately 13 weeks) adapted mixed martial arts class while the WLC group did not participate in any martial arts program between pre- and post-test. Children in both groups were administered a battery of standardized assessments and observational measures, including parent reports and laboratory-based tests of social and executive functioning. Results indicated that the MMA group had significantly lower social dysfunction, higher social skills, and better executive functioning (e.g., behavior and emotion regulation, working memory and cognitive flexibility) at post-test compared to the WLC group (effect sizes for the interaction effects of time by group ranged from .67 to 1.61). The intervention appeared to be efficacious in meeting its goals of improving the social skills and executive functioning of children with ASD. The study provides theoretical implications for the malleability of EFs in children with ASD, and practical implications for utilizing peer mediation to target social deficits.

## **Introduction**

### **Overview of Autism Spectrum Disorder**

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that is characterized by a myriad of deficits including challenges in social communication and the presence of restricted and/or repetitive behaviors and interests (American Psychiatric Association, 2013). Deficits in social communication and social interaction span contexts and include problems with reciprocity in social-emotional interactions (e.g., theory of mind, imaginative play) and verbal and nonverbal (e.g., eye contact, facial expressions) communication (American Psychiatric Association, 2013). ASD is also characterized by restricted, repetitive patterns of behavior or interests, such as repeated motor movements or speech, rigidity in routines or patterns, and atypically intense preoccupations with a limited range of interests (American Psychiatric Association, 2013). Symptoms of ASD cause clinically significant impairments in multiple domains of functioning, including social and occupational realms, especially if there are comorbid language or intellectual impairments (American Psychiatric Association, 2013). Additionally, there is a striking gender difference such that boys are more likely than girls to have an ASD diagnosis (1:42 v. 1:189; Centers for Disease Control and Prevention, 2016).

Individual functioning and development do not occur within a vacuum, and when embedded within a broader family context, impairments such as those associated with ASD extend beyond the individual with ASD to affect family functioning as well. Parents of children and adolescents with ASD are at risk for higher levels of stress due to child behavior problems (Lecavalier, Leone, & Wiltz, 2006); parents of children with ASD also experience higher levels of stress compared to parents of children with other developmental disabilities and parents of typically-developing (TD) children experiencing a normative course of development (Estes et al.,

2013). Furthermore, as children with ASD reach adolescence and adulthood, caregiver burdens may worsen in the form of poorer psychological well-being, such as increased anxiety and depressive symptoms (Barker, Hartley, & Seltzer, 2011).

On a more macro level, the impact of ASD also extends beyond the individual and family context to include the community. For example, within schools, teacher stress and burnout are higher among educators of children with ASD relative to educators who do not work in special education (Boe, Bobbit, & Cook, 1997; Hastings & Brown, 2002). The cost of ASD to the community is high, as special education teachers require more specialized training and institutional support in order to increase teacher retention and maintain high levels of professional self-efficacy (Gersten, Keating, Yovanoff, & Harniss, 2001; Jennett, Harris, & Mesibov, 2003; Lavelle et al. 2014; Schnorr, 1995).

Moving beyond the individual, family, and community levels, ASD is a broad economic and societal problem (Lavelle et al., 2014). In terms of prevalence, ASD affects 1% of the world's population and, within the United States, an estimated 1 in 68 children has been diagnosed with ASD (Centers for Disease Control and Prevention, 2016). With more than 3.5 million Americans living with ASD, caring for individuals with ASD comes at a steep economic price for the United States (Buescher, Cidav, Knapp, & Mandell, 2014). The cost of caring for adults with ASD, \$175-196 billion, far outweighs the cost of caring for children with ASD, \$61-66 billion, (Buescher et al., 2014). This difference may be due in part to the small proportion of adults with disabilities who are able to participate in the labor force (U.S. Bureau of Labor Statistics, 2017). Other contributing factors are the reliance on government-assisted funding of health care (Lavelle et al., 2014) and other supportive services for adults (e.g., housing). With the inclusion of direct (e.g., medical) and indirect (e.g., loss of earning potential) expenses incurred,

the economic cost of ASD to the United States was approximately \$268 billion in 2015. This estimate is projected to increase to \$461 billion by the year 2025 (Leigh & Du, 2015).

Fortunately, the societal cost of care for adults with ASD can be reduced, up to 2/3 in a Swedish sample, with early diagnosis and interventions during childhood (Jarbrink, 2007). Interventions that take place during childhood may ameliorate not only the core deficits of ASD, but sometimes bring corollary improvements as well (e.g., lessen behavior problems) (Vismara & Rogers, 2010). Taken together, interventions that effectively treat deficits of ASD in childhood can have benefits that extend beyond the immediate individual with ASD, and may accrue benefits at multiple levels over time.

### **Social Deficits in ASD**

In the present study, social functioning refers to two components: 1) the presence of and efficient use of appropriate social skills, and 2) the absence of social deficits and dysfunction, or problematic social behaviors (e.g., not using eye contact, hitting others). The deficits that define ASD are pervasive and include verbal challenges such as speech abnormalities and pragmatic language use as well as difficulties with nonverbal forms of communication (e.g., poor eye contact, displaying inappropriate facial affect, and not using communicative gestures) (American Psychiatric Association, 2013). These challenges occur in conjunction with social interaction difficulties such as not maintaining appropriate reciprocity during conversation, not understanding and abiding by social or cultural norms, and not interpreting and responding appropriately to social overtures (American Psychiatric Association, 2013; Baron-Cohen, 1988; Lord et al., 2000). These pervasive social deficits limit the individual's ability to effectively communicate and engage in social exchanges, which has consequences for interpersonal relationships as well as daily functioning (American Psychiatric Association, 2013).

**Early signs of social dysfunction.** Typically-developing infants show a preference for looking at face-like objects and patterns relative to non-faces (Ichikawa, Kanazawa, & Yamaguchi, 2011; Johnson, Dziurawiec, Ellis, & Morton, 1991). Within the first year of life, sustained attention and face-scanning behaviors emerge, and TD infants engage in organized visual scanning of faces (Haith, Bergman, & Moore, 1977; Nelson, 1987), as well as fixated attention to eyes and eye gaze (Brooks & Meltzoff, 2002; Meltzoff, 2007) and mouths (Hunnus & Geuze, 2004; Tenenbaum, Shah, Sobel, Malle, & Morgan, 2013). The ways in which TD infants respond to and process social information, such as information from faces, form crucial bases for social cognition and language learning (Key, Stone, & Williams, 2009). Infants and young children with ASD, however, do not naturally show these signs of orienting to social stimuli.

ASD symptoms emerge in the first two years of life (Zwaigenbaum, Bryson, & Garon, 2013), several years before a formal diagnosis is typically given. Retrospective parent-report and home-video studies have found that 12-month-old infants who are later diagnosed with ASD showed specific behavioral markers of autism such as low interest in social affect, reduced eye contact, low attention to human faces, repetitive vocalizations, and decreased positive affect particularly in social interactions (Goldberg, Thorsen, Osann, & Spence, 2008; Osterling & Dawson, 1994; Osterling, Dawson, & Munson, 2002; Ozonoff et al., 2010; Zwaigenbaum et al., 2005). Parents of high-risk infant siblings also report concerns with social-communication by the time these children reach their first birthdays (Sacrey et al., 2015).

Between 12- and 24-months of age, social eye gaze worsens among children later diagnosed with ASD (Werner & Dawson, 2005). By the time children reach their second birthdays, the inability to coordinate facial expressions with other social behaviors, such as eye

gaze, pointing, and vocalizations, is among the most salient signs of autism in young children later diagnosed with ASD, but they are not signs among children experiencing other developmental delays (Wetherby et al., 2004). By 24-months of age, children who consistently fail to respond to their names are at risk for developing ASD and are especially vulnerable to developing greater social impairments over the next 12 months (Miller et al., 2017).

Studies using eye-tracking technology with infants at high- versus low- risk of developing ASD have found that high-risk infants demonstrate reduced gaze to their mothers' eyes relative to low-risk infants (Merin, Young, Ozonoff, & Rogers, 2006). Even during simple attention tasks, young children with ASD are less likely to orient to social stimuli (e.g., clapping) compared to nonsocial stimuli (e.g., toy) (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Dawson et al., 2002). Social deficits observed in children with ASD, but not in children with other developmental delays, provide evidence that these deficits are unique to ASD. Furthermore, these observed early differences between children with and without ASD suggest that failures in basic social processes are neurologically based.

**Neurological basis of social deficits.** ASD became known as a “neurodevelopmental disorder” when the use of neuroimaging technologies began to map the behavioral symptoms of ASD onto the functional abnormalities in the brain structures and systems evidenced to be responsible for them (Toal, Murphy, & Murphy, 2005). Studies have introduced neural and behavioral models for brain-behavior relationships in ASD that begin early in life. Abnormalities observed in a network of neural regions responsible for the “social brain” (Brothers, 1990) provide evidence that ASD is based on structural and functional abnormalities in these neural circuitries. Specifically, several researchers have proposed that dysfunction in the amygdala, a collection of nuclei responsible for directing attention to faces and modulating emotions, may be

one of the causes of the social deficits that characterize ASD (Baron-Cohen et al., 1999; 2000). According to a review by Baron-Cohen and colleagues (2000), postmortem studies of the brains of individuals with ASD found that the volume and cellular density of the amygdala was relatively smaller than that of healthy controls (Rapin & Katzman, 1998). Furthermore, patients with no previous history of ASD who had suffered structural damage to the amygdala showed deficits in recognition of social emotions after this damage occurred (Adolphs, Baron-Cohen, & Tranel, 2002).

Another neural region that has been shown to be abnormal in ASD is the fusiform gyrus (FG), responsible for the visual processing of faces (Haxby, Hoffman, & Gobbini, 2002). Together with the amygdala, the FG has been observed to show low activation in adults with ASD when viewing faces and facial emotions (Baron-Cohen et al., 1999; Schultz et al., 2000). In addition, regions of the prefrontal cortex (PFC), specifically the ventrolateral and medial prefrontal cortex (VLPFC; MPFC), have been linked to the reward processing system (Cools, Clark, Owen, & Robbins, 2002; McClure, York, & Montague, 2004) and suggest that abnormalities in neural networks may be partly responsible for problems in the processing of social rewards in ASD (Baron-Cohen et al., 1999; Carrington & Bailey, 2009; Happé & Frith, 1996). Furthermore, the abnormalities in the processing of social rewards have been linked to two common challenges in ASD: theory of mind (ToM), the ability to make inferences about what other people know and think (Baron-Cohen, 2001; Happé, 1994), and mind-blindness, the inability to infer meaning in eye gaze, facial expressions, body language, and prosody (Baron-Cohen, 1997). Taken together, the growing neuroscience literature suggests that the root of social challenges in ASD is based in abnormalities in the neural systems that affect brain-behavior relationships and manifest in observable social dysfunctions. However, since experience also



exerts a profound influence on brain development, interventions not only affect behavior, but could possibly alter the neural functioning of the brain as well, as has been suggested by evidence from animal models (Champagne & Curley, 2005; Krech, Rosenzweig, & Bennett, 1966). Neural plasticity of experience-induced social behaviors could possibly alter the developmental trajectory of social functioning in ASD.

**Assessing social deficits in children with ASD.** Because social deficits are a core symptom of ASD, diagnostic tools used to assess symptomology and severity focus largely on these challenges, often enlisting caregivers as reporters of child developmental history (e.g., asking whether the child has ever used gestures to communicate or engaged in conversational turn-taking; Rutter, Bailey, & Lord, 2003). Caregivers can also report on the degree of social impairment and proficiency of social skills; different versions of rating forms have been developed to capture the perspectives of multiple reporters from different environments (Constantino, 2012; Gresham & Elliot, 2008). Past research has emphasized the added utility of observational methods to assess social behaviors with peers, such as initiating and responding to social overtures (Cunningham, 2012; Landa, 2005). These behaviors are then coded using behavioral coding schemes that have been validated for use with children with ASD. Behavioral observations are sensitive to change, and observable change is often directly attributed to the experimental treatment in studies involving a social skills intervention (Cunningham, 2012; Wolery & Garfinkle, 2002). The current study makes use of both parent reports and observational data in the assessment of children's social skills.

### **Executive Functioning Deficits in ASD**

In the present study, executive functioning can be viewed on a relative continuum as poorer to better executive functioning. Although not a core deficit, another challenge that most

individuals with ASD experience involves executive functions (EFs; Diamond, 2013; Hill, 2004; Ozonoff & Jensen, 1999), a host of inter-related cognitive processes that drive goal-directed behaviors. The umbrella term of EFs includes the three core processes of behavioral inhibition (i.e., the control and override of behavioral urges such as maintaining social politeness), working memory (i.e., holding information in mind while mentally manipulating it, such as doing mental arithmetic), and cognitive flexibility (i.e., adjusting to changed demands such as considering ideas from a new perspective) (Diamond & Lee, 2011). More complex EFs include verbal and nonverbal fluency (i.e., generating ideas and concepts such as listing words that start with a certain letter), and planning/problem solving, and reasoning (Anderson, 2002; Diamond, 2002; Diamond & Lee, 2011).

The first signs of core EFs in TD children emerge in the first year of life. Working memory emerges as early as 6-months of age, as measured by infant eye gaze following a distraction (Reznick, Morrow, Goldman, & Snyder, 2004). Behavioral inhibition and cognitive flexibility emerge during the following months. Through the use of the A-not-B task, a simple hiding task originally developed by Piaget (see Smith & Thelen, 2003, for a review), infants between 8- and 12-months of age have demonstrated early executive functioning skills through goal-oriented behavior to unveil a hidden toy; however, failures of executive functioning are common as infants perseverate and cannot control their response to reach towards the original location of the toy (Marcovitch & Zelazo, 1999; Piaget, 1954; 1963).

Important changes in executive functioning occur during the preschool years (2-5 years). In the second year of life, perseverative errors in inhibitory control and difficulty with cognitive flexibility continue. In one study, 2.5-year-old children were unable to use a scale model of a larger room to find a hidden object, whereas 3-year-old children succeeded at this task (Sharon &

DeLoache, 2003). By the end of the third year, children demonstrate even more improved behavioral inhibition and cognitive flexibility, both used in the pursuit of goal-directed behaviors (Hendry, Jones, & Charman, 2016).

Both core and complex EFs continue to develop and strengthen throughout early childhood and into middle childhood (9-11 years). Studies examining EFs in middle childhood focus on interventions to help improve EFs. For example, one study using martial arts training with TD children found that 4<sup>th</sup>- and 5<sup>th</sup>-graders benefited more from the intervention than kindergarten and 1<sup>st</sup>-graders, particularly in the areas of inhibitory control and working memory (Lakes & Hoyt, 2004). A computer-training study with 4- and 6-year-old TD children found no improvements in inhibitory control and working memory, and the authors suggest that the children could have been too young (Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2009) (see Diamond and Lee, 2011, for a review of EFs intervention studies). By the time children reach adolescence, performance on many standard executive functioning tests (e.g., Dimensional Change Card Sort; Zelazo, Müller, Frye, & Marcovitch, 2003; Wisconsin Car Sorting Test; Grant & Berg, 1948) is equivalent to an adult-level (Zelazo & Müller, 2010).

The developmental trajectory of EFs is widely heterogeneous across individuals with ASD (see Pellicano, 2012, for a review). Numerous studies have linked the associated deficits of neurodevelopmental disorders with poorer EFs (Zelazo & Müller, 2010) and with the growth trajectories of other sociocognitive abilities, such as language and ToM (Pellicano, 2012). Boys appear especially vulnerable to executive functioning problems (Diamond, 2002). In terms of cognitive deficits, when compared to TD peers, children with ASD demonstrate poorer EFs, particularly poorer planning abilities and cognitive flexibility (Hill, 2004). However, executive functioning deficits are not universal in ASD (Pellicano, 2010), and individual differences have

been documented (Pellicano, 2012). For example, some studies have found that working memory is an EF that remains relatively intact in high-functioning children and adolescents with ASD (e.g., Ozonoff & Strayer, 2001), whereas other studies found that working memory is indeed impaired, while recall and recognition memory may be left intact (e.g., Bennetto, Pennington, & Rogers, 1996). Thus, findings from prior studies suggest that individuals with ASD with deficits in some aspects of EFs may not be impaired in other EFs or in other cognitive domains.

**Neurological basis of executive functioning.** The prefrontal cortex (PFC), located in the frontal region of the cerebral cortex, is one of the slowest developing and last neural regions to reach full maturity, yet it is responsible for a host of crucial cognitive abilities. Within the neural circuit, the PFC is critical for engaging in tasks that are cognitively challenging, namely those that are novel, unpredictable, require a quick response, and that demand a significant amount of effort and concentration as opposed to tasks that rely on automatic responses (Diamond, 2000). The slow development of the PFC parallels the slow developmental trajectory of EFs (Diamond, 2002).

The executive functioning theory of ASD consists of two components, with the first proposing that dysfunctions stemming from structural and functional abnormalities in several brain regions, including the frontostriatal neural network and PFC more specifically, are responsible for executive functioning deficits in ASD (Gilbert, Bird, Brindley, Frith, & Burgess, 2008; Kana, Keller, Minshew, & Just, 2007; Luna et al., 2002;). Cognitive failures in executive functioning tasks, such as working memory, verbal fluency, and planning, have also been found in brain damaged patients with frontal lesions (Rapoport, van Reekum, & Mayberg, 2000; Schmahmann & Sherman, 1998). Within ASD, poor executive functioning may not be due to structural abnormalities alone, but rather to abnormalities in the connectivity and distribution of

activity between these frontal neural networks (Courchesne & Pierce, 2005; Just, Cherkassky, Keller, & Minshew, 2004). Past work suggests that increased connectivity within the PFC combined with diminished connectivity between the frontal cortex and other regions of the brain may in part be responsible for poorer executive functioning in ASD (Agam, Joseph, Barton, & Manoach, 2010; Kana et al., 2007; Schipul, Williams, Keller, Minshew, & Just, 2012). Imaging studies conducted with individuals with ASD have documented reduced activation and connectivity in several frontal brain regions, including more frontal activation during inhibition tasks (Schmitz et al., 2006) and lowered activation in the PFC during working memory tasks (Luna et al., 2002).

The second component of the executive functioning theory of ASD postulates a link between EFs and other areas of difficulty for ASD, such as ToM. Children's ToM, which has been linked to social deficits in ASD as discussed previously, has been inextricably linked to EFs. Individual differences in EFs have been found to predict the development of ToM among TD children (Carlson & Moses, 2001; Frye, Zelazo, & Palfai, 1995; Hughes & Ensor, 2007; Sabbagh, Xu, Carlson, Moses, & Lee, 2006) and children with ASD (Ozonoff & McEvoy, 1994; Ozonoff, Pennington, & Rogers, 1991; Pellicano, 2007, 2010). These studies suggest that EFs precede the development of ToM because EFs are required for the expression of ToM (Carlson & Moses, 2001; Pellicano 2007). For example, to consider another person's belief requires the inhibition of one's own belief. Similarly, working memory is involved in ToM such that one needs to maintain a certain perspective while simultaneously manipulating a new or alternative perspective to determine their association (Joseph & Tager-Flusberg, 2004). In order to change strategies or perspective during a conversation (e.g., when talking about a preferred topic, changing the level of jargon or details depending on whether the other person is familiar with

that topic), one must possess cognitive flexibility skills (Geurts, de Vries, & van den Bergh, 2014). Taken together, these studies highlight the important role of EFs in the development of social cognitive abilities such as ToM, and identify executive functioning deficits as one of the underlying causes of ToM impairments in ASD.

**ASD criteria and executive functions.** While cognitive dysfunctions are common but not core symptomology of ASD, restricted and repetitive patterns of behavior (RRBs) are indeed integral to the diagnostic criteria of ASD (American Psychiatric Association, 2013). RRBs consist of broad patterns of behaviors, actions, and thoughts that may include but are not limited to 1) intense preoccupations with interests (e.g., overly specific knowledge about a video game that hinders one's ability to talk about non-preferred topics), 2) strict and nonfunctional routines (e.g., compulsive need to be informed of all of the details of the day's events), 3) repetitive motor movements (e.g., hand flapping), and 4) nonfunctional use or close examination of parts of objects (e.g., spinning the wheels of a toy car) (Kim & Lord, 2010). RRBs are thought to develop from repetitive, self-stimulating motor movements present in infancy, and deficits may occur when there is a failure to replace these self-stimulating behaviors with more advanced skills that allow for more mature processing of sensory and environmental information (Thelen, 1979; Turner 1999). Severe RRBs hinder functioning as they cause perseveration on nonfunctional details and limit the ability to generalize or mentally shift previous knowledge to accommodate new information.

RRBs have been reported to be highly associated with some, but not all, impairments of EFs (Ozonoff & Schetter 2007; Turner, 1999). One study found that RRBs were only associated with behavioral inhibition (Boyd, McBee, Holtzclaw, Baranek, & Bodfish, 2009), whereas another study found that RRBs were associated with multiple executive processes including

behavioral inhibition, working memory, and cognitive flexibility, but not with planning and fluency (Lopez, Lincoln, Ozonoff, & Lai, 2005). In yet another study, partial support was found for the link between RRBs and EFs, but only for specific measures of RRBs, which weakened this association (South, Ozonoff, & McMahon, 2007). Though the mechanisms that link these two sets of processes are unclear, two hypotheses have been proposed (Turner, 1999). The inhibitory hypothesis posits that the inability to control and regulate behavior may cause repetition and perseveration on these inappropriate behaviors (Carlson & Moses, 2001). On the other hand, the generativity hypothesis postulates that failure in the ability to generate novel behaviors to new circumstances may induce reliance on defaulting to these repetitive behaviors; this has been observed especially in unstructured, novel contexts, when minimal support is provided to direct appropriate behavior (Jarrold, Boucher, & Smith, 1996; Turner 1999). Considering these mixed findings, although the examination of executive functioning deficits in ASD cannot fully account for the presence of RRBs, evidence suggests that they could partly explain the observed variety of RRBs that define ASD (Lopez et al., 2005).

**Assessing executive functioning in children with ASD.** EFs among children have been measured in many ways. In naturalistic contexts, parents and teachers have reported on behavioral functioning in relation to executive functioning abilities (Gioia, Isquith, Guy, & Kenworthy, 2000). A strength of utilizing caregiver and teacher reports is that its input has high ecological validity since deficits are expressed within the context of daily executive challenges, such as acting impulsively, having difficulty transitioning from one activity to another, and controlling negative emotions when faced with unexpected disappointment. EFs also have been measured using performance-based tests, either via computerized programs or researcher-administration. These performance-based tests are often administered in the laboratory, which

allows for a standardized, objective measure of executive functioning abilities and deficits.

Performance-based tests measure EFs by scoring variables such as response time, accuracy, and types of mistakes made (e.g., perseveration). In the present study, executive functioning abilities were assessed using both parent report and a computer-based task in the lab.

### **Interventions for Social and Executive Functioning Deficits**

Even though social deficits in ASD and executive functioning problems may cause impairment in daily functioning, they are not intractable. Social and EFs intervention studies have found that both domains are malleable and can be enhanced with practice (Diamond, Barnett, Thomas, & Munro, 2007; Diamond & Lee, 2011; Diamond, 2012; DiSalvo & Oswald, 2002; Rogers, 2000; Terpstra, et al, 2002). Most importantly, intervention studies with empirical support are consistent with the principles of evidence-based practice (Reichow, Volkmar, & Cicchetti, 2008).

There are a wide variety of interventions designed to improve social and executive functioning in children with ASD. The most common intervention is Applied Behavior Analysis (ABA), an intensive behavioral intervention used to remedy problem behaviors and build adaptive skills in children and adults with ASD (Lovaas, 1987; Lovaas & Smith, 1989; 2003; Virues-Ortega, 2010). Although ABA is effective for overall treatment of behavior problems (Matson, Hattier, & Belva, 2012; Matson & Minshawi, 2007), integrative approaches have been recommended to help promote an overall healthy lifestyle (Klein & Kemper, 2016) and give children with ASD opportunities for leisure activities that are social, physical, and informal (Hochhauser & Engel-Yeger, 2010).

The wide availability of treatment-based recreational activities suggests that supplementing ABA clinical treatments with treatment-based recreational and leisure activities



may provide exposure to different environments that also allow acquired skills to be practiced and generalized (Laushey & Heflin, 2000; Odom & Strain, 1984). Furthermore, recreational activities that double as treatments are especially promising because they fill a gap by providing activities that: 1) are interesting and enjoyable to the individual, 2) promote intrinsic motivation to participate, and 3) offer challenges that are attainable through effort, thus boosting self-esteem and confidence (Dattilo & Kleiber, 2002). Participation in treatment-based recreational activities is also important to supplement to the broader ABA treatment plan because social activities such as sports give children a break from traditional therapy while keeping them engaged in leisure, which is important for healthy quality of life (Garcia-Villamizar & Dattillo, 2010); recreational activities also provide opportunities to interact with other children. Children with ASD who participated in recreational activities were estimated by their caregivers to have higher quality of life during late adolescence/early adulthood compared to individuals with ASD who did not participate in such activities in childhood (Billstedt, Gillberg, & Gillberg, 2011). Although there are numerous recreational and therapy programs available to children with ASD, few are empirically-based with data on program efficacy vis-a-vis child outcomes; this missing step is crucial for evidence-based practice (Epp, 2008; Reichow et al., 2008, Reichow & Volkmar, 2010).

The studies that have tested recreational programs for children with ASD, although limited in number, have been wide-ranging, and have included the examination of social skills after a swimming intervention (Pan, 2010) and after art therapy (Epp, 2008), and the examination of stereotypy (repetitive, self-stimulatory body movements) after training in karate (Bahrami, Movahedi, Marandi, & Abedi, 2012). Studies such as these highlight the importance of investigating child outcomes following children's participation in adaptive recreational

programs. Although persistent dysfunctions in social communication and repetitive and restricted patterns of behaviors are core deficits of ASD, studies show that these areas are malleable even among individuals affected by ASD. Additionally, because these intervention programs vary in their design, with some using the same curriculum as TD children (e.g., Bahrami et al., 2012), and others specially adapted for children with ASD (e.g., Pan, 2010), they highlight the need to identify specific components of each program that directly map onto the gains in specific outcomes. These studies not only demonstrate the importance of intervention research, but also illuminate the challenges associated with this work. Together, prior research suggests that programs designed for children with ASD need to also be prepared to accommodate individual differences in symptomology and functioning. The present study aims to provide empirical data on a recreation-based intervention for children with ASD. Outcomes test for improvements in children's social and executive functioning abilities.

**Social deficit interventions.** Although there are numerous types of treatments for social deficits, each with its own respective strengths and weaknesses, for brevity, only the most widely used and empirically-tested interventions will be discussed here (see Reichow & Volkmar, 2010, and Vismara & Rogers, 2010, for more comprehensive reviews of other treatment types). ABA treatments, as discussed previously, have been used to treat many autism symptoms, including social deficits. In ABA interventions, children are usually prompted by an adult (the agent of intervention is commonly a parent or therapist, but peers are sometimes utilized as well; Reichow & Volkmar, 2010) to perform social behaviors, such as making eye contact and orienting to another person, and these behaviors are reinforced with extrinsic rewards (e.g., iPad time, food rewards) (Kennedy & Shukla, 1995; Lovaas & Smith, 1989; 2003; Reichow & Volkmar, 2010). ABA is effective in boosting social skills that may require prompting and

reinforcement (e.g., eye contact) (Owen-Deschryver, Carr, Cale, & Blakeley-Smith, 2008; Whalen & Schreibman, 2003), as well as those related to imitation and modeling (Garfinkle & Schwartz, 2002). ABA interventions are most frequently used among young, preschool-aged children with ASD (Strain & Schwartz, 2001). The frequency of ABA-use among young children with ASD suggests that these reinforced social behaviors are important foundations for social interaction, but also implies that possessing these skills alone are not sufficient for advanced social interactions (e.g., engaging in a meaningful social conversation) that arise later in childhood. Furthermore, adult-directed interventions like ABA limit the ability to generalize acquired skills to more naturalistic environments, thus indicating a need for more ecologically valid interventions with social interactions with peers (Rogers, 2000).

Another social intervention, social skills groups, consists of adult-mediated playgroups with school-aged children with ASD, and sometimes also include TD children (e.g., Kamps et al., 1992) (Rogers, 2000). Social skills groups may be more appropriate training environments for older children with ASD relative to younger children (Owens, Granader, Humphrey, & Baron-Cohen, 2008). Social skills groups focus on the development of more complex interaction skills rather than abide by a contingency-style of learning, and they provide peers in the same context so that children can practice learned skills. The effectiveness of social skills groups has generally been positive, although some studies have reported inconsistent findings (Reichow & Volkmar, 2010). Children with ASD who receive social skills group training have been reported to show improvements in social functioning, including social responsiveness and initiation, but parent and teacher reports have indicated that children face challenges in generalizing the learned skills to contexts outside of the group (Barry et al., 2003; Ozonoff & Miller, 1995). Furthermore, the examination of the effectiveness of social skills groups has been mixed in part because some

studies have implemented the intervention as the sole form of treatment, whereas others have included social skills groups as one part of a multi-component treatment plan (Reichow & Volkmar, 2010). To ensure that social skills groups continue to be effective outside of the clinic and without the constant support of an adult facilitator, children may need more opportunities to practice the learned skills with TD peers.

Peer-mediated approaches with TD children have been used to foster the development of social skills that can be generalized to naturalistic settings with peers (Bass & Mulick, 2007; DiSalvo & Oswald, 2002). The utilization of peer networks, which train and help TD peers understand how to model appropriate social behavior and how to interact with and support children with ASD, have been used in studies involving school-aged children with ASD (Garrison-Harrell, Kamps, & Kravitz, 1997; Kamps, Potucek, Lopez, Kravits, & Kemmerer, 1997). Following a peer-mediated intervention, kindergarten children with ASD not only showed gains in social skills, including an increase in initiations directed towards their TD “peer buddies,” but one child in the study maintained and generalized these skills to a new classroom setting in the first-grade (Laushey & Heflin, 2000). Skills obtained from peer-mediated interventions have also been generalized to other non-intervention settings (e.g., recess; Kamps et al., 1997). Of added benefit, TD peers have reported improved attitudes and higher acceptance of children with disabilities (Garrison-Harrell et al., 1997; Haring & Breen, 1992; Kamps et al., 1998). Thus, there may be reciprocal benefits to peer-mediated approaches to interventions. On the one hand, children with ASD are afforded the opportunity to interact with trained TD peers in a receptive environment, and in return, TD peers develop more positive attitudes towards autism (Campbell, 2006), and may become more accepting and motivated to continue their interactions with children with ASD. Increases in social initiations on the part of TD peers may help

reinforce the social skills learned by children with ASD and bolster the social bonds formed by both parties.

The use of peer-mediated approaches to socialization is consistent with developmental theory on peer socialization in childhood. Interactions with peers afford unique social experiences that are not obtained through interactions with adults. Peer interactions are more reciprocal than interactions with adults, as both children contribute to the social exchange (Piaget, 1977; Vandell, Nenide, & Van Winkle, 2006). However, interactions with an adult or more skilled peer are critical for the development of skills (Vygotsky, 1978). Interaction with a more skilled partner (such as an adult or a more capable peer) allows for an opportunity for the more expert partner to scaffold or support the novice to achieve a new skill that the novice would not have been able to achieve on their own, which Vygotsky referred to as the zone of proximal development. Vygotsky's theory states that the two partners strive to share intersubjectivity, which is a sense of mutual understanding acquired through interaction in a joint activity. This shared experience with a social partner enlists skills like ToM. Finally, Vygotsky suggested that ideal partners should not be equal, such that expert or more capable peers seem to serve as ideal partners to scaffold learning in a joint activity. Thus, peer socialization involving expert peers was a cornerstone to the present study. Approaches to social skills training have shown promising results and may also be effective in bolstering social skills among children with ASD in a setting of shared interest or activity. In the present study, TD peers were a key component of the intervention.

**Executive function interventions.** Intervention studies involving TD children also have been effective in the improvement of EFs (Diamond & Lee, 2011). One of the most well-researched approaches for improving EFs is computer-based training, which consists of

computerized games designed to challenge components of EFs with increasing difficulty (Diamond 2013; Diamond & Lee, 2011). Studies examining the effectiveness of computerized EFs training have been positive. Working memory appears to be the most frequently examined EF domain, as well as one of the most successfully enhanced with this technique.

In TD children, computerized training has been used to improve working memory and behavioral inhibition over the course of 5 weeks (Thorell et al., 2009). The findings indicated that children who received the computerized working memory program had significant improvements in working memory compared to children in the control group, but this effect was not found for the behavioral inhibition component. This finding suggests that working memory can indeed be trained via computerized programs, but behavioral inhibition is either not sensitive to this method, or this finding could indicate that various domains of EFs differ in their degree of malleability (Thorell et al., 2009).

Other studies have examined working memory training in children with more vulnerable developmental profiles, such as children with low academic performance and poor working memory (in the lowest percentile of verbal working memory; Holmes, Gathercole, & Dunning, 2009) and in children with ADHD (Klingberg et al., 2005). In these two studies, gains were seen in working memory after children received the computerized intervention. In the study with children with ADHD (Klingberg et al., 2005), behavioral inhibition improved as well. These studies are promising because they suggest that one or more EFs can be improved in children who may be at a cognitive or academic disadvantage. However, gains made from computerized training do not always generalize to other contexts; computerized training may need to be combined with other approaches to increase the generalizability of the improved skills (Diamond & Lee, 2011).

To supplement computer-based training, some school curricula have utilized mindfulness training to help train EFs. Mindfulness training consists of exercises intended to enhance attention to the present moment, heightening awareness to one's own experiences in response to the surrounding sensory and environmental stimuli (Bishop et al., 2004). Meditation and yoga are some ways in which mindfulness can be trained (Flook et al., 2010). In TD school-aged children, mindfulness training has been linked to improvements in EFs. Specifically, children with the poorest executive functioning performance at baseline showed the greatest gains following an 8-week mindfulness training intervention, and these gains were observed by both parents and teachers, suggesting that children succeeded in generalizing the learned skills to different settings (Flook et al., 2010). In the present study, the martial arts intervention included a mindfulness component similar to that used in studies by Lakes and colleagues (Lakes & Hoyt, 2004; Lakes et al., 2013).

Another way in which EFs can be enhanced is through physical activity or exercise. Regular aerobic exercise yields a variety of physical benefits, including improved cardiovascular health (Rognmo et al., 2012), weight loss and maintenance (Swift, Johannsen, Lavie, Earnest, & Church, 2014), and greater muscle strength (Crane, MacNeil, & Tarnopolsky, 2013). Physical activity is also beneficial for overall well-being, including prevention and treatment of mental illness (Blumenthal et al., 2012; Gallegos-Carrillo et al., 2012; Rozanski, 2012; Walsh, 2011).

Several studies have found that aerobic exercise reduces RRBs in children with ASD (Petrus et al., 2008). In one recent study, the intensity and frequency of stereotypic behaviors in 11.5- to 14.5-year-old children with ASD was measured 60 minutes after an exercise session of either 10 minutes of low-intensity exercise, 10 minutes of high-intensity exercise, 20 minutes of low-intensity exercise, or 20 minutes of high-intensity exercise (Schmitz et al., 2017). This study

found that stereotypic behaviors were reduced the most by the 10 minutes of low-intensity exercise condition, whereas the most strenuous condition, 20 minutes of high-intensity exercise, resulted in increased stereotypic behaviors.

Given that EFs are complex, higher-order cognitive abilities, studies that link physical activity to improved EFs suggest that complex neural processes occur during physical activity, thus altering brain function (Best, 2010; Davis et al., 2011). Children who engage in short bursts of exercise prior to cognitive testing have been observed to show immediate performance improvements in cognitive control, possibly due to immediate increases in neurochemicals in the neural system (Hillman et al., 2009). Sustained and frequent physical activity, though relying on different mechanisms, yields similar outcomes for EFs as those seen immediately after short bouts of exercise (Best, 2010). School-aged children who participated in sustained and frequent exercise programs showed improved executive functioning performance, specifically in planning ability and working memory; these gains were associated with increased neural activity in the frontal region and increased activation in the PFC regions responsible for EFs (Davis et al., 2011; Kamijo et al., 2011).

It is important to note that repetitive exercise alone is not sufficient for long-term gains in EFs. Rather, changes in the brain occur only when physical activities increase in complexity and are cognitively challenging (Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008). Thus, for physical activity to be effective in improving EFs, they must also require the active use of existing EFs, however limited they may be. That is, physical activity must recruit the use of frontal regions responsible for EFs in order to further make gains in this area (Budde et al., 2008; Diamond, 2000). In the current study, the martial arts intervention consisted of exercises that utilized increasingly complex cognitive processes.



**Martial arts interventions.** A physical activity that may be particularly effective in improving both social and executive functioning is martial arts training. Martial arts have traditionally been the epitome of the junction of physical rigor and cognitive complexity. The practice of martial arts is not only physically rigorous, but is qualified by self-discipline, respect for others, and teamwork, which renders it a potentially ideal activity for improving social and executive functioning deficits. Martial arts learning occurs in a social context, requiring an experienced senior martial artist to instruct a group of students. Furthermore, while team sports that prioritize social competitiveness and rely on team performance are sometimes anxiety-provoking for children with ASD, martial arts focus on self-improvement rather than social comparison or score-keeping. Together, these characteristics of martial arts complement the studies discussed previously in terms of characteristics of the most effective social and executive functioning interventions. Martial arts training may thus be an excellent strategy for improving deficits in these areas in children with ASD. A recent review identified only a handful of studies that have been conducted to date examining the use of martial arts to address social and behavioral functioning in individuals with ASD (Bell, Palace, Allen, & Nelson, 2016); three of the studies are reviewed below.

***Social deficits and martial arts.*** To date, only one known study has examined the role of martial arts on social dysfunction in children with ASD. In that study, Movahedi and colleagues (2013) recruited 15 children and adolescents with ASD to participate in Kata technique training, which is a component of the Japanese martial art style of Karate, and 15 participants with ASD to participate in a no-exercise control group (Movahedi, Bahrami, Marandi, & Abedi, 2013). Kata techniques, or “forms”, are sequences of striking and defensive techniques that increase in complexity with increasing expertise (Bahrami et al., 2012; Movahedi et al., 2013). Caregivers

and teachers were asked to report on the severity of children's social dysfunction pre- and post- the 14-week intervention, as well as at one month post-intervention. The intervention took place four times per week (56 sessions) at an indoor sports hall designed for martial arts classes. During the first 8 weeks, each session lasted 30 minutes; session length increased to 90 minutes for the remaining 6 weeks (Movahedi et al., 2013). Results indicated that children who received the Kata training were reported by caregiver and teacher consensus on the social interaction subscale to have less social dysfunction after the intervention. This improvement was maintained one month after the intervention ended; the no-exercise control group did not show significant changes (Movahedi et al., 2013). These findings suggest that a martial arts approach can be effective for decreasing social dysfunction in children with ASD. However, Movahedi and colleagues' (2013) relied on a measure of social behavior that only examined social dysfunction. In addition to decreases in social dysfunctions, there may also have been improvements in social skills, which were not examined. Replication and extension of this study is needed.

***Executive functions and martial arts.*** Martial arts have been found to be helpful in improving EFs in TD children. In a school-based martial arts program with 98 low-SES, TD children, 60 students' parents consented to individual assessments for the research study. Children were randomly assigned to receive a general PE class while the other half received Taekwondo (a Korean martial art style) sessions in lieu of their regular PE classes over the course of the 9-month academic year (Lakes et al., 2013). Classes were held for 40-45 minutes, five times per week. EFs were assessed via parent-report at baseline and at the end of the intervention. At the end of the intervention, students in the Taekwondo group showed significant improvements in behavioral inhibition compared to baseline scores (Lakes et al., 2013). A computer-based executive functioning assessment was also conducted with all children at the end

of the intervention; children in the Taekwondo group had higher executive functioning scores on measures of behavioral control, working memory, and cognitive flexibility compared to the children in the PE group.

Diamond (2012) has suggested that interventions aimed at improving EFs must also address other domains of development, such as emotional, social, and physical domains. Because development does not occur within compartmentalized domains, activities that are likely to be the most helpful for improving EFs are those that are not only cognitively challenging, but also are enjoyable and offer a sense of accomplishment (Diamond, 2012). These traits characterize many martial arts, and based on the Movahedi et al. (2013) study, seem suitable for children with ASD.

To date, only two known studies have implemented a martial arts intervention to address executive functioning deficits in children with ASD. As discussed previously, EFs may be partly responsible for symptoms of RRBs (Lopez et al., 2005). One study examined the malleability of stereotypic behaviors (e.g., hand flapping, finger flicking, and self-injury), which are types of RRBs (Bahrami, Movahedi, Marandi, & Abedi, 2012). Stereotypic behaviors were reported by caregivers and teachers, and a Kata technique training was implemented with the children and adolescents with ASD. The results indicated that participants who received the Kata intervention demonstrated reduced stereotypic behaviors both at post-test and at one-month follow-up compared to the baseline assessment; no differences were observed at pre-, post-, and one-month post-intervention for the participants in the no-exercise control group (Bahrami et al., 2012). Given that this study found lessened stereotypic behaviors following a martial arts intervention in children with ASD, and given that RRBs have been linked to EFs, a similar approach could yield benefits in EFs as well.

Chan and colleagues (2013) found improvements in a component of EF, self-control, in children with ASD following Nei Yang Gong (NYG), a mind-body exercise similar to Tai Chi (Chan, Sze, Siu, Lau, & Cheung, 2013). The researchers randomly assigned 48 children and adolescents (aged 6 to 17 years) to either the experimental group, which received training in NYG, or the control group, which received training on Progressive Muscle Relaxation (PMR), a relaxation training technique (Carlson & Hoyle, 1993). Participants' self-control abilities were measured using neuropsychological assessments including EFs (e.g., Tower of London Test), parent reports of behaviors, and an EEG assessment that was conducted while participants completed a Go/No-Go task. These measures were implemented before and after the one month intervention. Each of the interventions lasted one hour and took place twice a week for 4 weeks. The results indicated that at post-test, the NYG group had significantly higher parent-reported self-control, lower daily behavior problems, and increased EEG brain activity during the Go/No-Go task, compared to the PMR group; no group differences in performance were found at baseline. This multi-method study demonstrated that only 8 hours of martial arts training over the course of one month correlated with altered neural activity, improving self-control and decreasing behavioral problems in children and adolescents with ASD. Given the improvements in self-control observed in this study, we expect other domains of EFs to be influenced by martial arts training as well.

Based on the limited data, a martial arts approach to the treatment of social and executive functioning deficits in children with ASD is promising and has the potential for ecologically valid benefits. One issue in particular warrants further research attention: Martial arts interventions in the past have relied on the use of a single style of martial arts (e.g., Kata, Taekwondo, Nei Yang Gong). However, practicing only one style of martial arts may be

limiting. For example, one of the strengths of Taekwondo is that it is fast-paced, with rapid and complex footwork, yet this feature may not be attainable for students who have motor limitations, which are common in children with ASD (Jansiewicz et al., 2006). A calm martial art like Nei Yang Gong may be too slow-paced for American children, and may not offer the opportunity to practice social behaviors since it is an individual-based activity.

Because practicing only one martial art style may not be suitable for all children with ASD, a mixed martial arts (MMA) approach may be more appropriate. Modern-day MMA grew from Jeet Kune Do, developed by Hong Kong American martial artist Bruce Lee. Jeet Kune Do consists of consolidated elements and techniques from over 20 different martial arts with the primary philosophy of adapting to different strengths, as well as different contexts. MMA may be suitable for children with ASD for several reasons. First, children with ASD are widely diverse with different strengths and weaknesses; an adapted MMA intervention would provide students with a variety of tools that can be tailored to each student's individual abilities. Secondly, adapted MMA would teach students skills that can be generalized to different contexts, thus providing an opportunity to practice flexibly applying learned skills across contexts. Third, MMA could reduce stereotypic behaviors given that is a relatively low-intensity exercise; past research has recommended that low- to moderate-intensity exercise for children with ASD may be beneficial to help with behavioral inhibition of these stereotypic behaviors (Schmitz et al., 2017). The varying low to moderate intensity of MMA suits this recommendation. MMA is a promising intervention for improving social skills and EFs, and decreasing problematic behaviors because of its appropriateness for children with ASD, inclusion of TD peers, and opportunities for cognitively complex low-intensity exercise.

## **The Current Study**

The goals of the current study were to evaluate the effectiveness of a MMA intervention in improving social skills, decreasing social dysfunction, and improving EFs in children with ASD.

**Specific aim 1.** To examine caregiver-reported and researcher-observed social skills and social dysfunction preceding and following a MMA intervention designed specifically for children with ASD.

**Hypothesis 1.** Group status (mixed martial arts group versus waitlist control group) was expected to be a significant predictor of social skills improvement and lessening of social dysfunction at post-test, controlling for pre-test scores. Children with ASD who participated in an adapted MMA intervention were expected to show improvements in social skills and decreases in social dysfunction (i.e., problem behaviors) compared to children with ASD who did not receive the intervention.

**Rationale.** Past research has found that although social deficits are a core symptom of ASD, they can be ameliorated by social training exercises. Social training exercises that teach children with ASD how to initiate, respond, and maintain social interactions and social communications are crucial for functioning in a social world. However, generalizing learned skills to interactions with TD peers may be difficult if children with ASD only practice their skills with adults or with other children also affected by ASD. Peer-mediated intervention studies have found that training TD children in interacting with children with ASD renders them more effective agents of intervention than adults. Furthermore, evidence from Movehedi and colleagues (2013) found that social dysfunctions decreased in children with ASD who participated in the classes; the authors suggested that increased opportunities for practice of

social skills in combination with an increase in neurochemicals from physical activity may both be important contributors to decreasing social dysfunctions. Because the social relationship between the martial artist and training partner is more intimate relative to when interacting with teammates in non-martial arts sports, it was expected that the social benefits would be greater for children who trained martial arts relative to non-participation in the non-martial arts activities.

**Specific aim 2.** To examine caregiver-reported and laboratory-based assessment of executive functioning preceding and following a MMA intervention designed specifically for children with ASD.

**Hypothesis 2.** Group status (mixed martial arts group versus waitlist control group) was expected to be a significant predictor of executive functioning scores at post-test, controlling for pre-test scores. Children with ASD who participated in an adapted MMA intervention were expected to show improvements in executive functioning abilities, which included core EFs such as behavior inhibition, working memory, and cognitive flexibility, compared to children with ASD who did not receive the intervention.

**Rationale.** Current research has documented the malleability of EFs in TD children, as well as in children with developmental disorders including ASD. Approaches to improving EFs have found that some of the most effective interventions for long-term benefits are those that are cognitively challenging. Past research has used martial arts training to help children foster EFs, as sequences of martial arts techniques increase in complexity as the martial artist gains more experience. Martial arts have been documented to be effective in improving EFs because the training itself requires the active and frequent use of EFs. As such, the combination of rigorous physical activity and cognitively challenging tasks within the context of a MMA class was expected to contribute to gains in EFs among children with ASD. Because martial arts are both

physically rigorous and involve cognitively complex physical movements, participation in the martial arts intervention was expected to confer benefits in executive functioning, as has been supported by past research (e.g., Lakes & Hoyt, 2004).

**Specific aim 3.** To examine within-group associations between indicators of fidelity and post-test outcomes for participants in the MMA group.

**Hypothesis 3.** Two indicators of fidelity were expected to be associated with post-test outcomes for participants in the mixed martial arts group: 1) total minutes of intervention received, or “dosage”, and 2) number of days delay between pre- and post-test. More total minutes of intervention received were hypothesized to be positively associated with better scores on post-test measures of social and executive functioning measures. More days delay between pre- and post-test was expected to be associated with lower scores on the post-test outcomes of social and executive functioning.

**Rationale.** To ensure that the intervention would be implemented as it was intended at design (Dumas, Lynch, Laughlin, Smith, & Prinz, 2001), fidelity notes were taken by the author at each class session for the participants in the mixed martial arts group. Indicators of fidelity included the total minutes of intervention received and the days of delay between pre- and post-test. Total minutes of intervention received is treated as the dosage amount that each participant receives. As one might expect with a dose-response intervention study, the higher dosage that a participant receives, the greater the improvement. Days delay between pre- and post-test refers to the strength of the recommended dosage. Participants who take longer to complete the intervention (due to absences) should demonstrate weakened improvement given the dilution, or weakening, of the recommended dosage over time.



## **Method**

### **Recruitment**

Children with a clinical diagnosis of ASD were recruited from a database of families who previously had participated in research about autism and who consented to be contacted for future studies. Of the 26 families that fit the age and diagnostic criteria, 11 enrolled in the current study. Recruitment efforts were directed in part toward community organizations that serve families with ASD. Flyers were dropped off or sent electronically to local companies and treatment centers that provide services to families raising children with ASD. Interested families contacted the research team through email/phone or provided their contact information through a secure online survey. Families also were recruited from local autism treatment centers (10 interested, 5 enrolled) and physician offices or therapeutic clinic (5 interested, 3 enrolled). Flyers were distributed electronically to community autism advocacy and resource agencies (e.g., Help Me Grow Orange County, Talk About Curing Autism, Orange County Regional Center), which then distributed the flyers through email newsletters and Facebook postings. Through this recruitment avenue, families learned of the study through the organization's posts (16 interested, 12 enrolled). Flyers also were distributed at special events hosted by family-serving companies (3 interested, 2 enrolled), sports team practices (4 interested, 3 enrolled), and a school for children with special needs (1 interested and 1 enrolled).

Recruitment criteria targeted children between the ages of 8 and 11 years. This age range was selected based on the Lake & Hoyts (2004) study that found that the older children in their sample (4<sup>th</sup>- and 5<sup>th</sup>- grade) showed greater gains in EFs relative to younger children. This age range was also selected because of the normative emergence of complex EFs around age 8 to 9, and avoiding the confounding effects of the onset of puberty after around age 11 to 12.

Additional recruitment efforts were aimed at finding TD children to serve as peer buddies during the martial arts classes. Flyers were distributed to parents of children who were already enrolled as MMA students in the local martial arts academy where the intervention would take place. We did not try to match the gender of the TD peer buddies with the children with ASD because there were more boys with ASD than there were girls. However, we invited an equal number of TD boys and girls to volunteer as peer buddies.

### **Participants**

Participation in the current study was limited to children who met criteria for ASD. Several steps were involved in the determination of a valid ASD diagnosis. First, children had to have a parent-reported clinical diagnosis of ASD. Next, parents completed the parent-reported Lifetime Social Communication Questionnaire (SCQ; Rutter et al., 2003; see Measures for description) as a screening tool. Two of the children scored below the SCQ clinical cutoff of 12, with scores of 7 and 10. The author conducted an ADOS-2 assessment (Lord et al., 2012) at the university lab with all children who had the parent-reported clinical diagnosis. The diagnostic status of the two children who scored low on the SCQ and the other children all were confirmed using the ADOS-2; all children tested met ADOS-2 diagnostic criteria for ASD. Parents of participating children agreed not to enroll their children in any other martial arts classes during the study and confirmed that their child did not participate in any martial arts in the past year.

**Overall sample.** Thirty-four children (aged 8 – 11 years,  $M = 9.34$  years,  $SD = 1.08$ ) with a confirmed clinical diagnosis of ASD participated in the study. Consistent with 4:1 gender ratios of ASD reported nationally (U.S. Department of Health and Human Services, 2015), the majority of the sample was boys (82.4%,  $n = 28$ ). The overall sample was racially diverse, with 38.2% ( $n = 13$ ) Hispanic/Latino, 26.5% ( $n = 9$ ) Asian/Asian American, 23.5% ( $n = 8$ ) Caucasian/White

(Non-Hispanic), and 11.8% ( $n = 4$ ) multiracial or other. Using the WASI-II (Wechsler, 2011; see Measures for description), the Full-IQ score for total intellectual functioning was equivalent to low average for the sample as a whole, ( $M = 83.00$ ,  $SD = 19.96$ , range = 44 to 122). The verbal comprehension composite score was borderline (between extremely low and low average) ( $M = 79.24$ ,  $SD = 21.27$ , range = 45 to 115) and the perceptual reasoning composite score was low average ( $M = 89.35$ ,  $SD = 18.98$ , range = 51 to 124). ADOS-2 scores indicated that autism symptom severity was moderate to high ( $M = 7.00$ ,  $SD = 1.54$ , range = 4 to 10).

After completing pre-test study procedures at the university lab (see Design and Procedures below), children were randomly assigned to the MMA intervention group or waitlist control (WLC) group.

**Mixed Martial Arts (MMA) group.** Fourteen children (aged 8 – 11 years,  $M = 9.10$  years,  $SD = 1.10$ ) with a confirmed diagnosis of ASD participated in the MMA group, which consisted of two lab visits separated by the MMA intervention. The MMA subsample only included boys (100%,  $n = 14$ ) and was racially diverse, with 35.7% ( $n = 5$ ) Caucasian/White (Non-Hispanic), 35.7% ( $n = 5$ ) Asian/Asian American, and 28.6% ( $n = 4$ ) Hispanic/Latino. The Full-IQ score was equivalent to low average, ( $M = 80.36$ ,  $SD = 17.34$ , range = 44 to 110), the verbal comprehension composite score was borderline (between extremely low and low average) ( $M = 78.36$ ,  $SD = 20.23$ , range = 45 to 110), and the perceptual reasoning composite score was low average ( $M = 85.57$ ,  $SD = 16.64$ , range = 51 to 109). ADOS-2 scores indicated that autism symptom severity was moderate to high ( $M = 7.00$ ,  $SD = .78$ , range = 6 to 9). Characteristics of the MMA group are shown in Table 1. An additional four children in the MMA group were recruited and completed their pre-test assessment, but failed to return for post-test assessments due to voluntarily withdrawing from the intervention. All four children withdrew during the first

third of the intervention sessions. Three of the families that withdrew from the class cited a busy schedule and lack of time to continue participating in the intervention (two boys, aged 9.25 and 11.58 years, and one girl aged 10.50 years). One family reported the child lost interest in the class (one girl aged 8.08 years). This attrition subgroup of four participants did not differ from the final sample in terms of demographic and child characteristics (all  $t$ 's < .99,  $p$ 's < .05).

**Waitlist Control (WLC) group.** Twenty children (ages 8 – 11 years,  $M = 9.52$  years,  $SD = 1.07$ ) with a confirmed diagnosis of ASD participated in the WLC group, which consisted of two visits separated by a delay equivalent to the length of the intervention; during the delay, children did not participate in any martial arts programs. The majority of the WLC subsample was boys (70%,  $n = 14$ ). The WLC group consisted of 45% ( $n = 9$ ) Hispanic/Latino, 20% ( $n = 4$ ) Asian/Asian American, 20% ( $n = 4$ ) multiracial or other, and 15% ( $n = 3$ ) Caucasian/White (Non-Hispanic). Full scale IQ scores equated to low average ( $M = 84.85$ ,  $SD = 21.85$ , range = 44 to 122), the verbal comprehension composite score was borderline (between extremely low and low average) ( $M = 79.85$ ,  $SD = 22.47$ , range = 45 to 115) and the perceptual reasoning composite score was average ( $M = 92.00$ ,  $SD = 20.44$ , range = 51 to 124). ADOS scores indicated that autism symptom severity was primarily moderate to high ( $M = 7.00$ ,  $SD = 1.92$ , range = 4 to 10). Characteristics of the WLC group are shown in Table 1.

The MMA and WLC groups did not differ from one another in terms of demographic and child characteristics (all  $t$ 's < .08,  $p$ 's < .05), with the exception of child gender (significant) and ethnicity (marginal). Children's history of martial arts and sports participation (e.g., duration of prior martial arts participation and duration of past non-martial arts sports participation) did not differ by group (all  $t$ 's < .34,  $p$ 's < .05). Group comparisons on these variables are shown in Table 1.

Table 1. Demographic characteristics of study participants

	Mixed Martial Arts (MMA) <i>n</i> = 14	Waitlist Control (WLC) <i>n</i> = 20	Group differences (MMA vs. WLC)
<b>Child characteristics</b>	<i>n</i> (%)	<i>n</i> (%)	
Gender			
Female	0 (0%)	6 (30%)	
Male	14 (100%)	14 (70%)	<i>Fisher's exact test, p</i> = .03*
	<i>M</i> ( <i>SD</i> )	<i>M</i> ( <i>SD</i> )	
Child Age	9.10 (1.10)	9.52 (1.07)	<i>t</i> (32) = -1.10, <i>p</i> = .28
SCQ total	22.21 (4.58)	20.80 (7.16)	<i>t</i> (32) = .65, <i>p</i> = .52
ADOS-2 Comparison Score	7.00 (.78)	7.00 (1.92)	<i>t</i> (32) = .00, <i>p</i> = .10
WASI-II Full-Scale IQ	80.36 (17.34)	84.85 (21.85)	<i>t</i> (32) = -.64, <i>p</i> = .53
CBCL Internalizing Problems	61.00 (10.14)	63.80 (11.55)	<i>t</i> (32) = -.73, <i>p</i> = .47
CBCL Externalizing Problems	58.86 (8.65)	60.05 (11.53)	<i>t</i> (32) = -.33, <i>p</i> = .75
SRS-2 total	71.07 (7.40)	74.75 (8.38)	<i>t</i> (32) = -1.32, <i>p</i> = .20
Ethnicity	<i>n</i> (%)	<i>n</i> (%)	
Latino/Hispanic (non-Caucasian)	4 (28.6%)	9 (45%)	
White/Caucasian (non-Hispanic)	5 (35.7%)	3 (15%)	
Asian/Asian American	5 (35.7%)	4 (20%)	
Multiracial/other	0 (0%)	4 (20%)	<i>LR</i> <sup>1</sup> = 7.07, <i>p</i> = .07†
Prior Activity Participation			
prior martial arts	3 (21.4%)	6 (30%)	$\chi^2 = .31, p = .58$
prior sports	9 (64.3%)	15 (75%)	$\chi^2 = .46, p = .50$
	<i>M</i> ( <i>SD</i> )	<i>M</i> ( <i>SD</i> )	
Prior Activity Duration (months)			
Duration of prior martial arts	12.40 (10.71)	10.50 (8.09)	<i>t</i> (7) = 1.20, <i>p</i> = .27
Duration of prior sports	25.21 (22.99)	24.73 (26.37)	<i>t</i> (22) = -.10, <i>p</i> = .93
<b>Family characteristics</b>	<i>n</i> (%)	<i>n</i> (%)	
Income			
\$0-49,999	2 (14.3%)	4 (20%)	
\$50,000-99,999	6 (42.9%)	4 (20%)	
\$100,000-149,999	4 (28.6%)	7 (35%)	
\$150,000-199,999	2 (14.3%)	3 (15%)	
\$200,000-249,999	0 (0%)	0 (0%)	
\$250,000+	0 (0%)	2 (10%)	<i>LR</i> <sup>1</sup> = 3.82, <i>p</i> = .43
Maternal education (highest level)			
High school	4 (28.6%)	4 (20%)	
Post high school certificate/ specialized training	2 (14.3%)	2 (10%)	
Community college (AA)	3 (21.4%)	2 (10%)	
University/college (BA, BS)	3 (21.4%)	9 (45%)	
Graduate/professional degree	2 (14.3%)	3 (15%)	<i>LR</i> <sup>1</sup> = 2.48, <i>p</i> = .65
Child Living Arrangements			
Lives with both parents	12 (85.7%)	15 (75%)	
Lives with mother only	1 (7.1%)	1 (5%)	
Lives part-time with each parent (shared custody)	1 (7.1%)	4 (20%)	<i>LR</i> <sup>1</sup> = 1.20, <i>p</i> = .55

Note. <sup>1</sup>*LR* = Likelihood ratio for cell frequencies < 5.

†*p* < .10. \**p* < .05.

## **Design and Procedures**

Study procedures were approved by the university's institutional review board. Parents of children with ASD who indicated an interest in learning more about the study were contacted via telephone or email. A member of the research team described the study procedures and answered any questions that the parent had about the study. If the parent indicated a willingness to participate, the researcher scheduled a date for the family to come to the university testing space. Prior to the first scheduled visit, the researcher emailed the parent a link to an online survey with a battery of questionnaires, and a unique ID number. Parents read a study information sheet at the beginning of the online survey and provided implied consent by completing the survey. Parents were paid \$10 in cash or gift card for completing the online survey.

All participating children with ASD came to university for parent and child assessments. The first scheduled visit to the university testing space (two rooms) consisted of diagnostic and behavioral measures. A researcher met the family in the parking lot and walked with them to the testing space. After reviewing the consent form with a researcher, the parents signed informed consent statements indicating their willingness to take part in the behavioral portion of the study and to allow their child to participate in the study. During the parent consent process, another researcher described the study using child-friendly language to the child; a "test of understanding" was given, as requested by the University IRB committee. Children were asked four "Yes/No" questions about the study (e.g., "I don't have to be in the study if I don't want to," and "I can stop being in the study at any time and I won't get in trouble"). Children who answered 3 of the 4 questions correctly were judged as cognitively competent to give verbal assent, and did so to the research team. Children who did not pass the test of understanding were

not assented, but still participated in the study if their parent provided written consent; all the parents provided written consent for their child to be involved in the study.

Following consent and assent procedures, the author administered the IQ assessment, the Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II; Wechsler, 2011; see Measures for description). Only the lead author and child were in the testing room. Concurrently, in a separate room, one parent ( $n = 27$  mothers) of the child completed cognitive and social questionnaires about their child with a research assistant present. Next, the child was offered a brief break. The author then administered the Autism Diagnostic Observation Schedule – Second Edition (ADOS-2; Lord et al., 2012; see Measures for description) to the child. The parent remained in a separate room for the ADOS-2 unless the child’s language ability required the parent to be present during the ADOS-2 administration (see Measures for information on ADOS-2 Modules). After the ADOS-2, the child was offered another brief break. With only the child and a researcher in the room, the child was then administered a computerized executive functioning test (see Hearts & Flowers test under Measures and Instruments).

At this time, a second family from this study (another child participant with ASD) was scheduled to arrive at the university testing space in order to conduct the social interaction assessment. While the first child completed the computerized executive functioning test with the researcher, another researcher greeted the second family, escorted them to the lab rooms, and administered the consent and assent procedures. After the second family consented to participate in the study, a researcher accompanied both children as they were administered the social interaction task together in the testing room. Both sets of parents were in one room while the two children were in a separate room to complete the social interaction task. Following the administration of the social interaction task, members of the first family who had been

administered all the study procedures were escorted to the parking lot and left the university. The second family stayed at the university testing space and were administered the remaining study procedures: WASI-II, parent questionnaires, ADOS-2, and computerized executive functioning test. Each family was paid \$20 in cash or gift card at the end of their first visit.

Following the first laboratory visit, children were randomly assigned to either participate in the MMA or Waitlist control (WLC) group. The intervention was designed to last 13 weeks (91 days). At the end of the intervention period, children returned to the university testing space for post-test assessments. All of the participants in the MMA group were tested within three days of their last intervention class session. For the post-test assessment, a researcher administered the Hearts & Flowers test to the child while their parent completed questionnaires with a different researcher in a separate room. Next, a second family (different from pre-test) arrived, and a researcher administered the social interaction task with the two children. Following the social interaction task, the first family was escorted to the parking lot to leave. The second family stayed so that a researcher could administer the Hearts & Flowers test again to the child while their parent completed questionnaires with another researcher in a separate room. Each family was paid \$20 in cash or gift card at the end of their second visit.

### **Description of MMA intervention for Children with ASD**

The MMA intervention was specially designed for children with ASD. The author, who has a background in MMA and in working with children with ASD, collaborated with a team of senior martial arts instructors and program coordinators at the local martial arts academy to design the class structure and content. The owner and CEO of the local martial arts academy funded the program, which was free to the families with ASD. The number of children with ASD in each class session was recorded with a target number of no more than 12 children with ASD



per class. If children took brief breaks from the class session, this was also recorded. Classes were taught by a senior instructor and an assistant instructor, and two to three adult facilitators (see Head instructor and adult-facilitators section below).

**Intervention dosage.** The intensity of the intervention, or dosage, was modeled on a prior study that implemented a martial arts intervention with children. The current study chose to follow the dosage used by Lakes & Hoyt (2004) with TD children in kindergarten through 5th grade given that the age of participants in the current study intentionally matched the ages in the Lakes and Hoyt (2004) study. This element of the design was expected to increase the likelihood of the children being able to complete the full intervention. The intervention for the present study consisted of 26 class sessions over the course of 13 weeks; this schedule resulted in training taking place two times per week with each class session lasting 45 minutes, yielding a targeted total of 1170 minutes of intervention time (similar to the total minutes in the Lakes & Hoyt, 2004). If children did not miss any of the class sessions and attended twice per week, it would take them 91 days to obtain the recommended dosage for this study.

**Curriculum.** The curriculum was designed to be implemented in thirds. In the first third, participants learned simple two- and three-step combinations of strikes and kicks that were used only on a punching mitt or kicking pad. Behavior inhibition was used to attend to the instructor's demonstrations. These sessions also practiced working memory, as the children had to remember the different rules that they learned, and move different parts of their bodies in accordance with the rules. In the second third of the curriculum, participants extended these skills and learned glove-drills (i.e., "partner drilling," or working directly on a partner's body) and grappling, which had more steps than the first component and also involved more details. The sessions in the second third also emphasized working memory along with behavior inhibition and cognitive

flexibility. Behavior inhibition was taught when working with a partner so that children did not hit or kick their partner with excessive force as one would when practicing with a mitt or pad. Children also were taught cognitive flexibility when asked to mentally manipulate what was previously learned to accommodate the new information as it was presented. In the last third of the curriculum, participants combined all their learned skills, which consisted of highly detailed, multi-step techniques, which required the active use of the three core EFs.

This increasingly complex curriculum over the course of 13 weeks required the active use of all three core EFs. Because the techniques were difficult, children were expected to become frustrated. Meditation and breathing exercises were practiced at the beginning of the class (see Class Structure below), and children were reminded to use their breathing techniques to help regulate their emotions if they became frustrated or overwhelmed. Indeed, the present intervention was different than past studies that simply took curriculum used in a class with TD students and implemented it with an ASD population. The present curriculum was specifically designed to address the challenges in executive functioning faced by children with ASD by teaching multiple tools, incrementally making them more complex and challenging multiple components of EFs, and flexibly applying and generalizing the learned skills across a variety of contexts. For a martial arts intervention to be effective, it must include these important components.

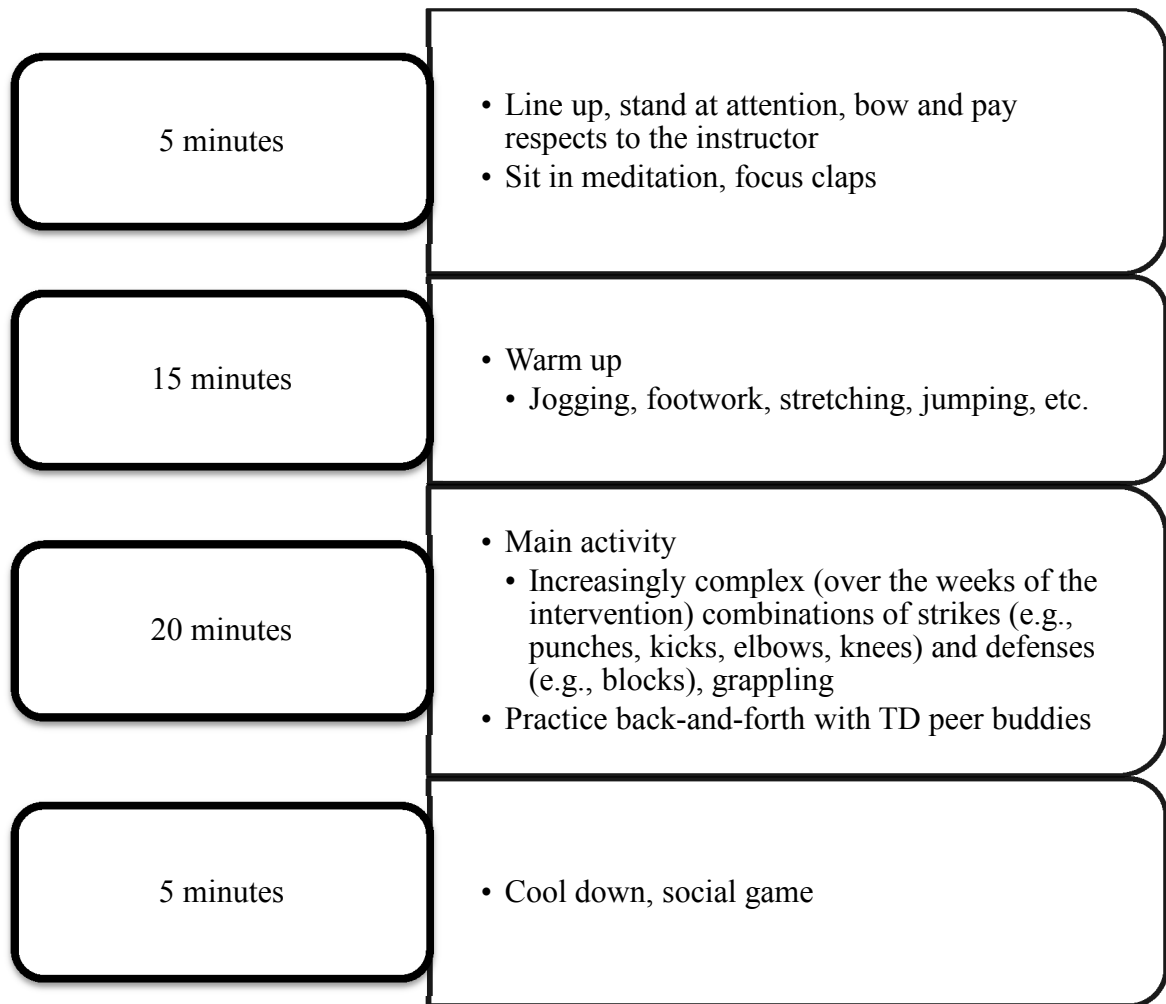
**Peer buddies.** A key component of the adapted MMA curriculum was the inclusion of the peer buddies, who were TD martial arts students of the academy. Peer buddies ranged in age from 8 to 13 years and were selected based on their instructors' overall judgment of the peer's maturity and demonstrated behavior in class (e.g., helping others, good judgment, being a good role model, etc.). Peer buddies were unaware of the research study, so they were blind to which

participants were in the study. Prior to the start of the intervention, peer buddies were extensively trained by the author in how to engage with children with ASD, specifically in how to model socially appropriate behaviors in class (e.g., lining up, standing at attention, bowing), facilitate participation, and initiate and respond to social interactions. Each peer buddy underwent approximately 4 hours of training over the course of 1 month. At each class, the number of TD peer buddies was recorded, with a target minimum of three peer buddies per class session. The gender composition of the TD peer buddies was also recorded, with a target minimum of 2 TD boys for each class session. Peer buddies were not specifically assigned to any one child with ASD for the entire duration of the intervention, as martial arts traditionally encourage working with different partners to learn how to adapt and generalize skills. However, partnerships rotated each class and interactions between each peer buddy and each child with ASD were at least twice per class. The peer buddies volunteered their time to assist in the class; they did not receive monetary compensation, but were incentivized with a free weekly Thai Kickboxing class.

**Head instructor and adult-facilitators.** The head and assistant instructors of the class were senior instructors at the martial arts academy with extensive experience in teaching martial arts to children of wide age ranges and abilities, including children with developmental disabilities such as ASD, cerebral palsy, and Down syndrome. In addition to the head and assistant instructors, adult facilitators (undergraduate research assistants) provided additional support to the children with ASD and peer buddies. Prior to the start of the intervention, the instructors were trained by the author in how to further adapt the teaching of martial arts to children with ASD. For example, the author trained the adult facilitators in how to intervene in situations that were too difficult for peer buddies to handle, such as extreme behavior challenges (e.g., tantrums, aggression, fleeing). Adult facilitators also assisted by redirecting attention when

needed. Notes were taken on the number of martial arts instructors and adult facilitators assisting in each class, with the target number of one head instructor and one assistant instructor, and at least two adult facilitators. Because eligibility requirements for the present study did not screen for child functioning level, we expected there to be children who initially required additional adult support to participate in the class. As a result, adult facilitators sometimes provided one-to-one support to children who were lower-functioning until they were able to participate independently. The number of classes that had children who required additional one-to-one support from an adult facilitator was recorded for each class, with the expectation that children would have the most trouble while adjusting to the first third of the intervention. Because there were children with ASD in the class that were not enrolled in the research study, instructors were blind to which children were in the research study. The instructors volunteered their time to teach the class; they did not receive monetary compensation.

**Class structure.** The 45 minutes of each class session were allocated as follows (see Figure 1): 1) 5 minutes to line up, stand at attention, bow and pay respects to the instructor, and sit in meditation; during meditation, students are instructed to focus on their breathing and think about questions that promote self-monitoring, namely “Where am I?”, “What am I doing?”, and “What should I be doing?” (Lakes & Hoyt, 2004, p.289), as well as “What am I working for today?”; 2) 15 minutes to warm up (e.g., jogging, stretching, jumping), and 3) 20 minutes for the main activity, which consisted of increasingly complex (over the weeks of the intervention; the curriculum was divided into thirds) combinations of strikes (e.g., punches, kicks, elbows, knees), defenses (e.g., blocks), and basic grappling, with opportunities to perform the learned curriculum and practice this back-and-forth with peer buddies, and 4) 5 minutes for cool-down games (e.g., red light-green light to practice starting and stopping one’s body, dodgeball).



*Figure 1.* Class structure that was followed for each class session

## Measures and Instruments

**Demographics and background information.** Parents reported on family demographic information, such as family income, racial and ethnic background, sibling information, and parent employment, marriage status, and education. Information about the child’s medical and developmental history was also collected, including history of therapies received (see Appendix A for demographics and background information questionnaire).

**ASD diagnostic measures.** Diagnostic measures were obtained both by parent-report and direct assessment of the child by the author. The diagnostic measures were only taken at pre-test given that they were unlikely to change over the course of 3 months.

***Lifetime Social Communication Questionnaire.*** The Lifetime Social Communication Questionnaire (SCQ; Rutter et al., 2003) is 40-item parent report tool used by clinicians to quickly screen for ASD. In research, it has been used to confirm parent report of a clinical ASD diagnosis (e.g., DeRosier, Swick, Davis, McMillen, & Matthews, 2011; Matthews, Goldberg, & Lukowski, 2013). The questionnaire takes less than 10 minutes to complete, and parents responded “Yes” or “No” to questions that describe certain behaviors that are related to impairments in communication (e.g., Can you have a to and fro ‘conversation’ with her/him that involves taking turns or building on what you have said?”), social functioning (e.g., “Has her/his facial expression usually seemed appropriate to the particular situation, as far as you could tell?”), and stereotyped or restrictive behaviors (e.g., “Has she/he ever had any interests that preoccupy her/him and might seem odd to other people, e.g., traffic lights, drainpipes, or timetables?”). Responses were summed to yield a total score. Higher scores indicate poorer social communication. SCQ scores of 12 or higher combined with parent report of a clinical diagnosis are consistent with the gold standard ASD diagnostic assessment (Daniels et al., 2012).

***Autism Diagnostic Observation Schedule – Second Edition.*** The Autism Diagnostic Observation Schedule – Second Edition (ADOS-2) is a standardized, semi-structured, observational assessment of ASD consisting of modules appropriate for infants through adulthood (Lord et al., 2012). The assessment takes 40–60 minutes, during which a trained administrator (i.e., the author in the present study) serves as a social partner during activities designed to elicit behaviors that fall within two main domains characteristic of ASD: 1) social

affect (e.g., eye-contact, reciprocal social communication, appropriate facial affect), and 2) restricted and repetitive behaviors (e.g., unusual sensory interests in play material/person, compulsions or rituals). Behaviors were coded and converted into algorithm scores, which were then summed to yield a total score that allowed for comparison of a child's autism symptomology to other children with ASD of similar age and language ability. Higher scores indicate more severe autism symptomology. The ADOS-2 is the gold standard for the behavioral assessment of ASD with demonstrated reliability and validity when conducted by trained administrators (Lord et al., 2012).

Each child is administered one of three child-aged modules on the ADOS-2, selected on the basis of the child's overall expressive language level (Lord et al., 2012). Module 1 is designed for use with children who are pre-verbal or use single words and do not consistently use phrase speech. Module 2 is designed for use with children who consistently communicate in phrases but are not yet verbally fluent. Module 3 is designed for use with children who use fluent speech that includes complex, logical, and flexible use of sentences and grammar (Lord et al., 2012).

**Child intellectual and behavioral functioning.** Intellectual functioning was obtained by direct assessment of the child by the author, and child behavioral functioning was assessed by parent-report. The intellectual and behavioral measures were only taken at pre-test.

***Wechsler Abbreviated Scale of Intelligence – Second Edition.*** The Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II) is a brief measure of intelligence in individuals 6 – 90 years of age. It is used to screen for intellectual disabilities or giftedness and to determine whether additional in-depth assessments are needed (Wechsler, 2011). The WASI-II includes four subtests: Block design, vocabulary, matrix reasoning, and similarities.

Performance on the subtests yield verbal comprehension (vocabulary and similarities) subscores, perceptual reasoning (block design and matrix reasoning) subscores, and a full-scale IQ score. Scores on the WASI-II can be used to estimate IQ score ranges on the two comprehensive Wechsler intelligence scales (WISC-IV and WAIS-IV; Wechsler, 2011). The WASI-II takes 15–30 minutes to administer and has been used successfully with children and adults with ASD (Minshew, Turner, & Goldstein, 2005). Higher scores indicate greater intellectual functioning.

***Child Behavior Checklist – School age.*** Parents completed the Child Behavior Checklist (CBCL) for school-aged children ages 6 -18 to indicate children’s problem behaviors. Using a 3-point scale, parents were asked to respond to 113 items concerning the presence of behaviors. Raw scores on the Internalizing and Externalizing problems subscales were converted to T-scores per the scoring instructions. Higher scores indicate more problem behaviors. The CBCL has been reported to demonstrate good reliability (Achenbach & Rescorla, 2001) and validity (Cohen, Gotlieb, Kershner, & Wehrspann, 1985). The CBCL can be completed in 20 minutes.

***Social Responsiveness Scale-2.*** The Social Responsiveness Scale-2 (SRS-2) is a 65-item parent-report rating scale that measures social impairment among individuals with ASD. The SRS-2 measures domains of social responsiveness such as social awareness, social cognition, social communication, social motivation, and restricted interests and repetitive behavior (Constantino, 2012). The SRS-2 total raw score was converted to a T-score per the scoring instructions. Higher scores indicate greater deficiency in social responsiveness and greater severity of RRBs. The form has been validated for use from 2.5 years to adulthood and takes 15 – 20 minutes to complete.

**Child social functioning.** Parent reports and laboratory observations were used to assess the social functioning of children at pre- and post-test.



***Social Skills Improvement System.*** The Social Skills Improvement System (SSIS; Gresham & Elliot, 2008) replaces the Social Skills Rating System (SSRS; Gresham & Elliott, 1990) that has been used in previous research (Koning & Magill-Evans, 2001; Oord et al., 2005; Ozonoff & Miller, 1995) to evaluate social skills (e.g., takes turns in conversations) and problem behaviors (e.g., force others to act against their will) across multiple reporters, including parents, teachers, and children themselves in different contexts such as home, school, and the community. The SSIS has been validated for use with children as young as preschool-aged until grade 12 (Gresham, Elliott, Vance, & Cook, 2011) and has higher internal consistency compared to the former SSRS, as well as updated norms and new subscales. Parents rated the frequency of desirable and undesirable social behaviors, from 0 (Never) to 2 (Very often). The SSIS raw scores were converted to standard scores per scoring instructions. Standard scores loaded onto two scales (social skills and problem behaviors). Higher scores on the *social skills scale* (SSS) indicates higher social competence. Higher scores on the *problem behaviors scale* (PBS) indicates more problem behaviors. The SSIS typically takes approximately 15 – 25 minutes to complete. The SSIS was given to parents both at pre-test and post-test.

***Social interaction task.*** A behavioral observation of each child was conducted pre- and post- intervention as a means of assessing the quality of children's social behavior during a semi-structured interaction with another child with ASD. Children were scheduled to be paired together in a laboratory play interaction and were matched on gender, age (plus or minus 2 years), and language ability (as measured by parent report during scheduling over the phone; parents rated their child as “nonverbal,” “speaks in short phrases,” or “has fluent conversations”). At both the pre- and post-test observations, the two children in the interaction were not familiar with one another and had not interacted in the past in order to remove familiarity as a possible

confound. At post-test, to preserve the element of unfamiliarity, children from the MMA group were paired with children from the WLC, since they had become familiar with other children in the MMA group after participating in the intervention. We chose to pair children with ASD with one another, as opposed to with TD confederates, for two reasons. The first was so that we could collect data on two participants at once. The second was because of the power-dynamic between two children with ASD; as mentioned previously, “expert” peers tend to scaffold the interactions with less experienced play partners. As such, the goal of the behavioral observation was to evaluate children’s social behaviors when paired with a relatively “equal” peer who was unlikely to scaffold the interaction in the same way as an adult or TD peer would. The intent was to allow for opportunities for children with ASD to generate spontaneous initiations and responses during the interaction, which may be indicative of generalized skills developed in other contexts.

During the behavioral observation, the two children were allowed 3 minutes to interact freely to build rapport. General toys (e.g., blocks) were available for free play and to help the children become more comfortable with one another. Next, the researcher put away the free play toys, and a modified version of the Pep Board Task (Hertz-Lazarowitz, Kagan, Sharan, Slavin, & Webb, 2013; Gelb & Jacobson 1988; Pepitone, 1980) was used to prompt interaction of the two children. A researcher presented each dyad of unfamiliar children with a set of plastic pattern blocks manufactured by Learning Resources Company to make pictures in a 3D pattern. Each dyad was provided with a bucket of 250 blocks of six different shapes and colors. Each 1-cm thick block was affixed with a small piece of Velcro on the back so that it could be securely attached to a patterned board (see Appendix B for pattern board sample). There were multiple patterned boards that each made up a picture of an object familiar to most school-aged children (e.g., cat, flower). Each rectangular board was made of 1.3-cm poster board and covered with

Velcro so that the children could fasten the blocks onto the pattern board to complete the picture of the object.

Of the dyad, one child was randomly selected to be the first “leader” in the interaction; random selection was used to ensure that each child had an equal opportunity to be the more “dominant” person in the interaction (i.e., the individual in possession of the blocks) first. The leader was given a pattern board and the bucket of blocks. The researcher asked the children to work together to complete the picture using the blocks. The researcher also directed the children to plan their work before beginning, which has shown to increase peer interaction in past research using this task (Gelb & Jacobson 1988; Pepitone, 1980). The children were then given 5 minutes to complete this picture. If they finished early, they were given an additional pattern board without further instruction, until the time was up. When the 5 minutes were up, the researcher put the used blocks back into the bucket. Next, the other child in the dyad became the new “leader.” The new leader was given a new pattern board and the bucket of blocks. The same instructions were given regarding working together and planning to complete the picture using the blocks. Children were given another 5 minutes to complete the pictures.

The order of presentation of the pattern boards were counterbalanced across all dyads so that each picture was presented first an equal number of times. The task was video recorded. The researcher remained in the room to monitor the children, but interacted with the children only to provide the initial instructions. If verbal initiations were made towards the researcher, she responded with, “I don’t know,” or “Try your best,” without offering suggestions or helping with the task or with facilitating social interaction. The total interaction lasted 15 minutes: 3 minutes for familiarization, 1 minute for researcher instructions, 5 minutes for the first “leader”, 1 minute for researcher instructions, 5 minutes for the second “leader.”

Two trained observers (with a target inter-observer agreement level of 85% or more) coded the video files for social behaviors made by each of the children during the interaction task (Bauminger, 2002). Observers were blind to the condition of the participants. Social behaviors were coded using the behavior coding scheme for children with autism, originally developed by Hauck and colleagues (1995), which examined social initiations of children with ASD in positive (e.g., sharing objects), negative (e.g., avoidance), and low-level (e.g., looking) social interactions (Hauck, Fein, Waterhouse, & Feinstein, 1995). For her study with children with ASD, Bauminger (2002) extended the scheme to include social responses in addition to social initiations. She also added categories that included a wider variety of behaviors that are performed by higher functioning children with ASD (e.g., verbal sharing of experiences, teasing). In the present study, each child in the dyad was coded for the frequency of social interactions that were either *positive*, *negative*, and *low-level* in their valence, over the 15-minute task (see Appendix C for definitions of observed social behaviors used for coding social interaction task; Bauminger, 2002). Observers recorded the total number of interactions within 10-second intervals (see Appendix D for coding sheet used by observers). Items were summed to yield the frequency of social interaction valence (i.e., number of exchanges that were positive, negative, and low-level) of the social interaction. The summed values reflect social interactions that children directed towards one another over the course of the 15-minute task.

**Child executive functioning.** Parent-reports, researcher administered, and computerized tasks were used to measure executive functions at pre- and post-test.

***Behavior Rating Inventory of Executive Function.*** The Behavior Rating Inventory of Executive Function (BRIEF) is an 86-item parent and teacher rating scale designed to assess executive functioning and self-regulation in children and adolescents ages 5 – 18 years (Gioia et

al., 2000). The BRIEF takes 10 – 15 minutes to complete (Gioia et al., 2000). Parents were given the BRIEF at pre- and post-test and reported on children's functioning on three indexes of EFs, with each index consisting of multiple clinical scales: *Behavior Regulation Index* (BRI; scales: inhibit, self-monitor), *Emotion Regulation Index* (ERI; scales: shift, emotional control), and *Cognitive Regulation Index* (CRI; scales: initiate, working memory, plan/organize, task-monitor, organization of materials). The three indexes were combined according to the scoring instructions to yield a *Global Executive Composite* (GEC) score. Higher scores indicate poorer executive functioning on all the scales, indexes and composite scores (Gioia et al., 2000).

***Hearts & Flowers test.*** The Hearts & Flowers test (also known as the Dots task in some studies) is a computerized task that measures all three core EFs: working memory, inhibition, and cognitive flexibility (Davidson, Amso, Anderson, & Diamond, 2006; Diamond et al., 2007). The 8-minute test can be used to measure EFs in children as young as 4 years old and through adulthood (Davidson et al., 2006). In the present study, the Hearts & Flowers test was given at both pre- and post-test using a touch-screen laptop computer. A researcher instructed children to place their hands in the same location and position in front of the screen so that all children maintained the same distance from the screen. The left index finger was to be used to press the button on the left side of the screen, and the right index finger was to be used to press the button on the right side of the screen.

Sample stimuli of the Hearts & Flowers test is provided in Appendix E. In the first block, the congruent block, a heart-shaped stimulus appeared on one side of the computer screen and participants were instructed to press a button on the same side of the stimulus (i.e., if the heart appeared on the left side of the screen, participants used their left index finger to press the button on the left side of the screen). The congruent block required the use of working memory because

the participant had to mentally hold a rule in place (i.e., hearts equals same side) and respond by pressing the correct button (with their left or right hand) (Wright & Diamond, 2014).

In the incongruent block, a flower-shaped stimulus appeared on one side of the screen and participants were instructed to press the button on the opposite side of the screen (i.e., if the flower appeared on the left side of the screen, participants used their right index finger to press the button on the right side of the screen). The incongruent block also required the use of working memory to hold and mentally work with the rule (i.e., flowers equals other side) and respond by pressing the correct button. In addition to working memory, the incongruent block required the use of behavioral inhibition (Wright & Diamond, 2014). Wright & Diamond (2014) noted that in the incongruent trial, both adult and child participants must actively inhibit their tendency to respond by pressing the button on the same side as the stimulus (known as the Simon effect, spatial incompatibility effect, or stimulus-response incompatibility; see Wright & Diamond, 2014 for a review of the literature). In both the congruent and incongruent blocks, participants were allowed practice trials until they understood the rule for each. There were 12 trials for each block (not including the practice trials).

Finally, the mixed block consisted of both congruent and incongruent trials (Diamond et al., 2007); there was no practice for the mixed block, which had 49 trials. Just like the congruent and incongruent blocks, the mixed block required the use of working memory and behavioral inhibition. It also required the use of cognitive flexibility, as participants needed to quickly and flexibly switch between the two rules (Wright & Diamond, 2014).

Executive functioning performance for each of three blocks (congruent, incongruent, and mixed) was measured for two dependent variables, *accuracy* and *response time* (in milliseconds, *ms*). Per the scoring instructions, trials with response times less than 250 *ms* were excluded from

the analyses for being too fast (Wright & Diamond, 2014). *Accuracy* was then computed by dividing the total number of correct responses over total number of responses (that were greater than 250 *ms*). Next, trials with incorrect responses were excluded from the response times; median response time was calculated for correct responses only (Davidson et al., 2006). Per the instructions, median response times were used instead of the mean values to reduce the effects of outliers.

## **Results**

### **Plan of Analysis**

For Specific Aim 1 and 2, mixed-effects regression models were conducted to examine the relationship between group status (MMA group versus WLC group) and time (pre- versus post-test scores) on the target variables: SSIS (i.e., social skills and problem behaviors), social interaction task (i.e., positive and low-level; negative interactions were excluded from the data analysis because they rarely occurred; mean frequency of negative interactions ranged from 0 to 2.08). BRIEF (i.e., Behavior Regulation, Emotion Regulation, Cognitive Regulation, and Global Executive Functioning Composite), and Hearts & Flowers test (i.e., accuracy and response times for the congruent, incongruent, and mixed blocks), using statistical software Stata-15 (StataCorp., 2017). Overall intervention group and time effects were tested by examining the regression coefficients in the mixed-effect regression models.

Two sets of effect sizes were calculated. The first was Cohen's classic *d*-index, the standardized difference in post-intervention group means. Cohen (1988)'s definitions of effect sizes as small ( $d = .2$ ), medium ( $d = .5$ ), and large ( $d = .8$ ) were used to interpret the magnitude of Cohen's *d*-index change scores on the outcome measures (see below). It is important to note that Cohen intended for these categories be used for calculating power, and not to be used as

benchmarks for assessing the magnitude of effects observed in intervention research (Lipsey et al., 2012).

In order to balance convention with emerging best practice, a second set of effect sizes, Cohen's d-index change scores, was calculated. The d-index change score has been used in previous intervention research (e.g., Sheridan, Bovaird, Glover, Garbacz, & Witte, 2012). In the present study, it was used to calculate the effect sizes for the interaction effects of time (pre- vs. post-test) by group (MMA vs. WLC) on outcome measures. The d-index change score compared the average pre- to post-test change score for the treatment versus control group (A. Dent, personal communication, October 26, 2017).

$$d_{change} = \frac{M_{MMA\ change} - M_{WLC\ change}}{SD_{weighted}}$$

Positive d-index change scores indicate the MMA group had the higher scores; negative d-index change scores indicate the WLC had the higher scores.

To address Specific Aim 3, Spearman correlation analyses were conducted within the MMA group to examine the association between indicators of fidelity (i.e., the total intervention dosage that each participant received in minutes, and days delay between pre- and post-test) and post-test social and executive functioning measures.

### **Power Analysis**

Power analysis was conducted using GPower software. Power was set at 95% (Cohen, 1988). The total sample size required for a small effect size of Cohen's  $f^2 = 0.14$  is 114; the total sample size required for a medium effect size of Cohen's  $f^2 = 0.39$  is 43, and the total sample size required for a large effect size of Cohen's  $f^2 = 0.59$  is 30. With the current total sample size of 34, the present study had enough power to detect large effects of statistical significance, but lacked sufficient power to find moderate or small effects.



## **Preliminary Analyses**

**Demographic variables.** Following data screening, demographic variables and individual characteristics (e.g., family income, child gender, child age) as well as scores obtained from the diagnostic measures (e.g., SCQ, ADOS-2, WASI-II Full-scale IQ, CBCL, and SRS-2) were examined for group differences. Only child gender significantly differed between the two groups, with more boys in the MMA group (Table 1). This was to be expected given that the majority of the overall sample was boys.

Demographic variables such as individual characteristics (i.e., child gender, child ethnicity, child age, and prior activity participation), and family variables (i.e., family income, maternal education, child living arrangements), and scores obtained from the diagnostic measures (e.g., SCQ, ADOS-2, WASI-II Full-scale IQ, CBCL, and SRS-2) were examined for group differences at pre-test (see Table 1). Child gender significantly differed between the MMA and WLC group, in that the MMA group was 100% boys and the WLC was 70% boys. Because both groups were majority boys and to preserve power, I did not control for gender in the analyses. Means and standard deviations for major study variables by group and time are presented in Table 2. T-tests were also conducted to test for order effects of the first versus second families (i.e., the order of which the families were scheduled to be tested first or second; see Design and Procedures above) at each lab visit; there was no evidence of order effects at both pre- and post-test on the respective outcome measures ( $p$  values from .14 to .92).

Table 2. Means and SDs for major study variables by experimental group and time

	Mixed Martial Arts (MMA)		Waitlist Control (WLC)	
	<i>n</i> = 14		<i>n</i> = 20	
	<i>M</i> ( <i>SD</i> )		<i>M</i> ( <i>SD</i> )	
	Pre: Time 1	Post: Time 2	Pre: Time 1	Post: Time 2
<u>Social Skills Improvement System (SSIS)</u>				
Social Skills	68.36 (13.70)	76.36 (14.48)	73.85 (18.63)	72.25 (18.19)
Problem Behaviors	125.36 (8.99)	117.14 (10.44)	126.15 (14.02)	130.10 (13.59)
<u>Social Interaction Task</u>				
Positive	7.92 (6.24)	11.54 (11.43)	11.39 (13.11)	14.27 (14.34)
Low-level	19.08 (8.12)	23.15 (16.99)	26.61 (19.03)	20.07 (13.54)
<u>Executive Function: Behavior Rating Inventory (BRIEF)</u>				
Behavior Regulation	71.36 (9.03)	67.79 (8.70)	72.35 (9.48)	73.15 (8.42)
Emotion Regulation	69.21 (9.36)	66.21 (8.91)	73.15 (8.96)	75.55 (8.47)
Cognitive Regulation	69.21 (7.71)	67.29 (7.79)	68.90 (8.86)	69.10 (7.87)
Global Executive Functioning Composite	74.93 (8.87)	71.71 (8.54)	74.70 (9.34)	75.85 (7.81)
<u>Executive Function: Hearts &amp; Flowers Test</u>				
Accuracy (% correct)				
Congruent block	91.57 (13.08)	96.86 (9.48)	93.83 (12.51)	89.35 (15.79)
Incongruent block	68.04 (36.13)	79.56 (24.84)	74.81 (25.12)	83.27 (21.52)
Mixed block	61.85 (19.98)	72.01 (17.55)	62.60 (15.21)	63.17 (15.88)
Response Time ( <i>ms</i> <sup>1</sup> )				
Congruent block	622.25 (217.21)	555.43 (121.65)	584.68 (236.45)	575.73 (190.27)
Incongruent block	647.89 (156.00)	588.61 (172.89)	598.63 (168.77)	622.45 (161.06)
Mixed block	629.32 (173.55)	642.39 (137.32)	666.53 (120.62)	669.65 (136.14)

Note. <sup>1</sup> *ms* = milliseconds.

To determine if parent-reported and lab-based measures assessed different components of social and executive functioning, Spearman correlation analyses were conducted to examine associations between parent-reported (SSIS and BRIEF) and lab-based (social interaction task, Hearts & Flowers test) measures of social and executive functioning. Parent-reported social skills on the SSIS, but not parent-reported problem behaviors, had a significant association with the social interaction task; higher parent-reported social skills was positively associated with more positive interactions at pre-test; see Table 3). For the two measures of executive functioning, there was one significant correlation between accuracy on the Hearts & Flowers test and parent-reported EF; poorer parent-reported emotion regulation on the BRIEF was positively associated with higher accuracy in the congruent block at pre-test. For response time on the

Hearts & Flowers test, only response time for the mixed block yielded associations with the indexes of parent-reported executive functioning. As shown in Table 3, response time in the mixed block of the Hearts & Flowers test was positively associated with poorer parent-reported executive functioning for the behavior regulation, cognitive regulation, and global executive functioning scales at both pre- and post-test.

Finally, to examine whether prior participation in sports might have given some children an advantage over those without sports experience, Spearman correlation analyses were conducted across all participants who previously indicated prior sports participation ( $n = 24$ ) to examine the association between the duration of prior sports participation (in months) and pre-test social and executive functioning. The results indicated no significant associations between prior sports participation and pre-test social and executive functioning (all  $p$ 's  $< .05$  and all coefficients were less than  $r = .29$ ).

**Pretreatment comparability.** Children were randomly assigned to group. The two groups were compared for selection effects (differences on pre-test scores). As expected, none of the pre-test scores on main study variables were significantly different between the groups ( $p$  values from .15 to .94).

Table 3. Spearman correlation analyses of associations between parent-reported and lab-based measures at pre-test (top row) and post-test (bottom row) ( $n = 34$ )

Lab-based Measures	SSIS <sup>1</sup> : Parent- reported Social Skills	SSIS <sup>1</sup> : Parent- reported Problem Behaviors		
Social Interaction Task				
Positive	.41* .34†	.32† .02		
Low-level	.01 -.03	-.16 -.11		
	BRIEF <sup>2</sup> : Parent- reported Behavior Regulation	BRIEF <sup>2</sup> : Parent- reported Emotion Regulation	BRIEF <sup>2</sup> : Parent- reported Cognitive Regulation	BRIEF <sup>2</sup> : Parent- reported Global Composite <sup>3</sup>
Executive Function: Hearts & Flowers Test				
Accuracy (% correct)				
Congruent block	.08 -.14	.35* -.05	.16 -.10	.21 -.19
Incongruent block	.05 .15	.08 .24	-.08 .13	-.05 .23
Mixed block	.07 .06	.09 -.11	.13 .15	.05 .05
Response Time ( $ms$ <sup>4</sup> )				
Congruent block	-.02 -.06	-.11 -.17	.01 -.16	.02 -.17
Incongruent block	.20 .26	.12 .24	.11 .25	.14 .28
Mixed block	.51** .42*	.29† .13	.47** .46**	.44** .37*

Notes. <sup>1</sup> SSIS = Social Skills Improvement System. <sup>2</sup> BRIEF = Behavior Rating Inventory of Executive Function. <sup>3</sup> Global Composite = Global Executive Functioning Composite. <sup>4</sup>  $ms$  = milliseconds.  
† $p < .10$ . \* $p < .05$ . \*\* $p < .01$ .

**Intervention sessions and fidelity checks.** Sessions were assessed for fidelity, or the adherence to the intervention protocol in terms of frequency, duration, dose, and content (Carroll et al., 2007). Implementation fidelity for adherence to the protocol variables was computed by taking the ratio of the actual protocol variable over the intended protocol variable. Frequency of intervention implementation averaged 22.86 ( $SD = 2.51$ ) for total number of sessions for each participant. Implementation fidelity for adherence to the frequency of the intervention was 87.90% (22.86 actual sessions / 26 intended sessions). Duration of intervention implementation averaged 124.64 days ( $SD = 27.90$ ) for each participant. Implementation fidelity for adherence to the duration of the intervention was 73% (124.64 actual days / 91 intended days). Dose (i.e., coverage or the total number of minutes of intervention for each child) was 995.22 minutes ( $SD = 257.14$ ). Implementation fidelity for adherence to the coverage of the intervention was 85.06% (995.22 actual minutes / 1170 intended minutes).

Intervention content fidelity included the average number of TD peer buddies per class session ( $M = 2.86$ ,  $SD = 2.22$ ); implementation fidelity for adherence to the number of TD peer buddies was 95.33%; there were 2.86 actual peer buddies / 3 intended peer buddies. The gender composition of the TD peer buddies averaged nearly 2 ( $M = 1.88$  boys,  $SD = 1.75$ ); implementation fidelity for adherence to the gender composition of peer buddies was 94%; 1.88 actual boys / 2 intended boys. The number of instructors was close to 2 ( $M = 1.74$ ,  $SD = .52$ ); implementation fidelity for adherence to the number of instructors was 87%; 1.74 actual instructors / 2 intended instructors. The number of adult facilitators was almost 2 ( $M = 1.94$ ,  $SD = 1.03$ ; implementation fidelity for adherence to the number of adult facilitators was 97%; 1.94 actual facilitators / 2 intended facilitators). The number of children with ASD in each class session averaged 5 ( $M = 5.03$ ,  $SD = 2.07$ ; range = 2 to 11); since the maximum number of

children with ASD was  $n = 11$ , implementation fidelity for adherence to the maximum number of children with ASD in each class was 100%; it took four cohorts of running the intervention to obtain the present sample size. Finally, the percentage of class sessions requiring a one-to-one aide for support a lower-functioning child was less than half (Sum = 40.79%); implementation fidelity was 80.90%; 40.79% actual sessions / 33% intended sessions.

To reduce attrition and to ensure that the children receiving the martial arts intervention did not vary greatly in the amount of intervention dosage received, an “attendance bonus” (i.e., additional compensation) was offered to families of children who missed no more than three class sessions during the intervention period. However, all the families in the MMA group missed a minimum of 6 class sessions, thus extending the intervention period for those individuals and resulting in a later-than-anticipated post-test date. As a result, the attendance bonus was not given to any of the families.

### **Mixed-effects Regression Models on Social Skills**

Specific Aim 1, to examine caregiver-reported and researcher-observed social skills and social dysfunction following a MMA intervention, was examined using a linear mixed-effects model. Group status (MMA group versus WLC group), Time (pre- versus post-test), and their interaction were posited as the predictors of the parent report of social skills (Social Skills and Problem Behavior scale scores on the SSIS) and of social behaviors obtained from the social interaction task (frequency of social initiation by valence: positive and low-level). For the analyses examining parent report on social skills, there was no significant main effect of time ( $b = 2.35, p = .13$ ). However, results indicated a significant interaction between group and predicted social skills over time, such that the MMA group had 9.60 higher social skills standard

score at post-test, as compared to the WLC group and controlling for pre-test scores, with a large effect size of  $d_{change} = 1.19$  (Table 4; Figure 2).

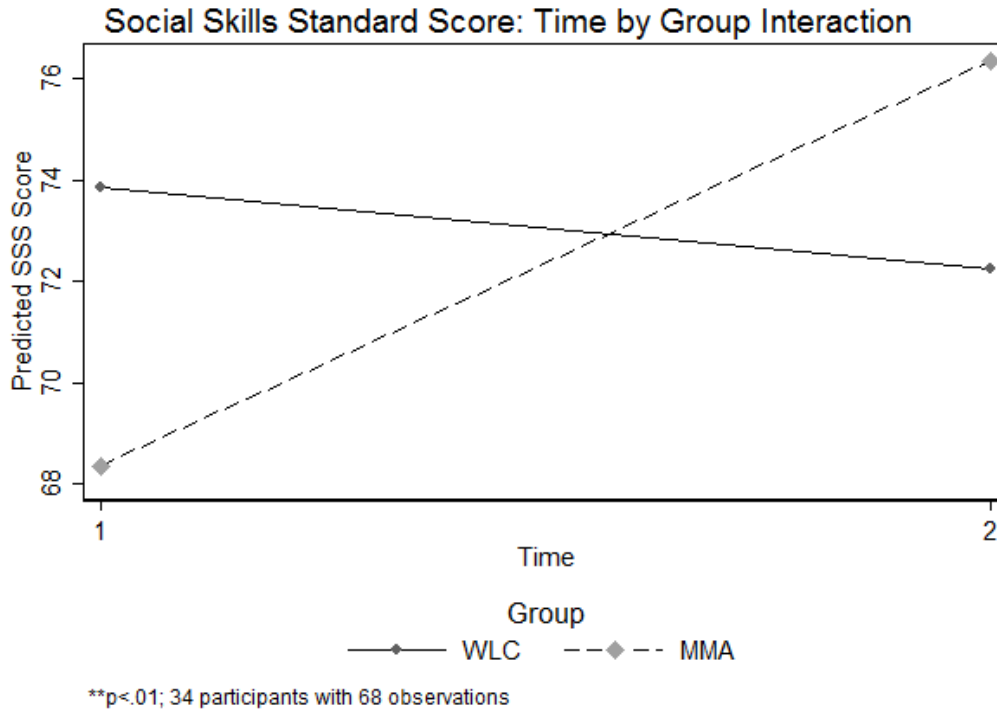


Figure 2. Time by group interaction on parent-reported SSIS Social Skills

Results indicated no main effect of time for problem behaviors ( $b = -1.06, p = .52$ ). However, results indicated a significant interaction between group and predicted problem behaviors over time, such that the MMA group had 12.16 lower problem behaviors standard score at post-test, as compared to the WLC group and controlling for pre-test scores, with a large effect size of  $d_{change} = -1.61$  (Table 4; Figure 3).

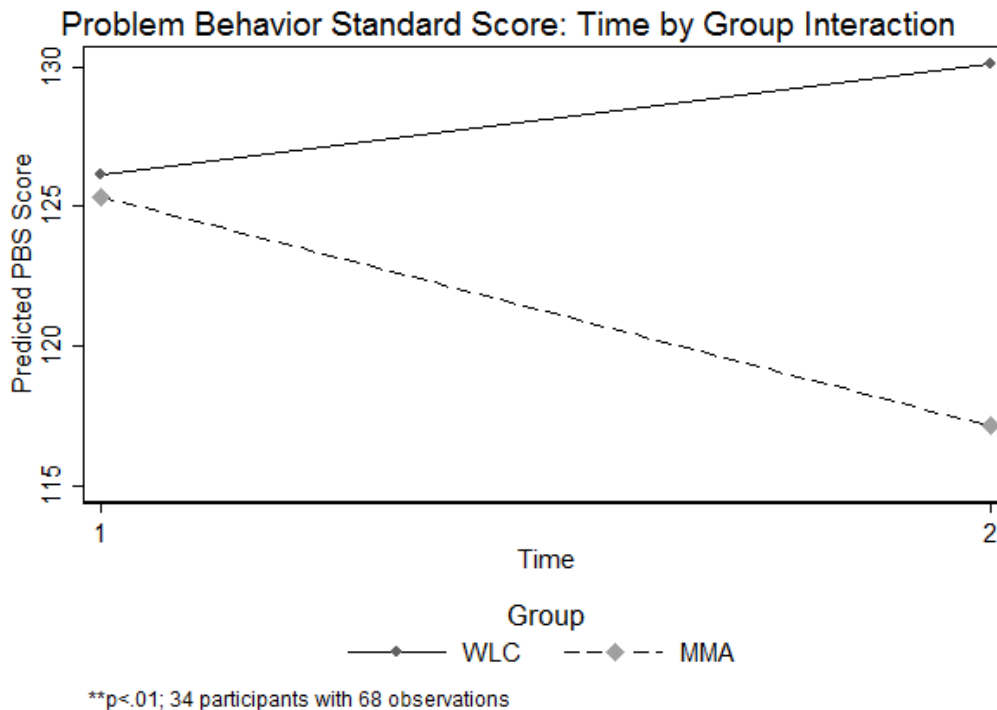


Figure 3. Time by group interaction on parent-reported SSIS Problem Behaviors

In terms of the frequency of positive and low-level social interactions coded from the social interaction task, there were no significant main effects of time, or significant interactions between group and valence of social interactions (positive or low-level) over time (Table 4). Effect sizes ranged from small to medium ( $d_{change} = .28$  to  $.68$ ). The hypothesis for Specific Aim 1, that the social skills would be higher at post-test for the MMA group compared to the WLC, was supported for parent-reports of social skills and problem behaviors on the SSIS, and not supported for the objective social behaviors within the context of the social interaction task.



Table 4. Multilevel between-subjects effects of martial arts intervention on post-test social and executive functioning scores (MMA:  $n = 14$ , WLC:  $n = 20$ )

Variable	Coefficient <sup>1</sup>	SE	Effect size $d_{classic}$ <sup>2</sup>	Effect size $d_{change}$ <sup>3</sup>
Social Skills Improvement System (SSIS) <sup>4</sup>				
Social Skills	9.60**	2.73	.24	1.19
Problem Behaviors	-12.16**	2.59	-1.04	-1.61
Social Interaction Task <sup>5</sup>				
Positive	-0.97	3.53	-.21	.28
Low-level	6.53	5.61	.20	.68
Executive Function: Behavior Rating Inventory (BRIEF) <sup>4</sup>				
Behavior Regulation	-4.37*	2.19	-.63	-.67
Emotion Regulation	-5.40**	2.08	-1.08	-.88
Cognitive Regulation	-2.13	1.65	-.23	-.46
Global Executive Functioning Composite	-4.36*	1.84	-.51	-.81
Executive Function: Hearts & Flowers Test <sup>4</sup>				
Accuracy (% correct)				
Congruent block	9.77*	4.10	.55	.83
Incongruent block	3.07	6.89	-.16	2.17
Mixed block	9.58**	3.20	.53	1.01
Response Time ( $ms$ ) <sup>6</sup>				
Congruent block	-57.87	63.55	-.12	-.31
Incongruent block	-83.11	54.97	-.20	-.56
Mixed block	9.95	56.01	-.20	.06

Notes. <sup>1</sup> WLC group as the reference group. <sup>2</sup>  $d_{classic}$  = Cohen's classic d-index of post-intervention group means;  $d = (\text{mean treatment group} - \text{mean control group})/sd_{pooled}$ . <sup>3</sup>  $d_{change}$  = Cohen's d-index of change scores;  $d_{change} = (\text{mean treatment group change score} - \text{mean control group change score})/sd_{weighted}$ . <sup>4</sup> Based on 34 participants with 68 observations. <sup>5</sup> Based on 31 participants with 57 observations. <sup>6</sup>  $ms$  = milliseconds. \* $p < .05$ . \*\* $p < .01$ .

### Mixed-effects Regression Models on Executive Functioning

Specific Aim 2, to examine caregiver-reported and researcher-observed executive functioning following a MMA intervention, was examined using a linear mixed-effects model. Group status (MMA group versus WLC group), Time (pre- versus post-test), and their interaction were posited as the predictors of the parent report of executive functioning (BRI, ERI, CRI, and GEC on the BRIEF) and of performance on the Hearts & Flowers test (accuracy and response times on the congruent, incongruent, and mixed blocks). For the analyses examining parent report on the BRIEF, results indicated no main effect of time ( $b = -1.00$ ,  $p = .30$ ). However, there was a statistically significant interaction between group and predicted behavior

regulation over time, such that the MMA group had 4.37 lower BRI score at post-test, as compared to the WLC group and controlling for pre-test scores, with a medium to large effect size of  $d_{change} = -.67$  (Table 4; Figure 4).

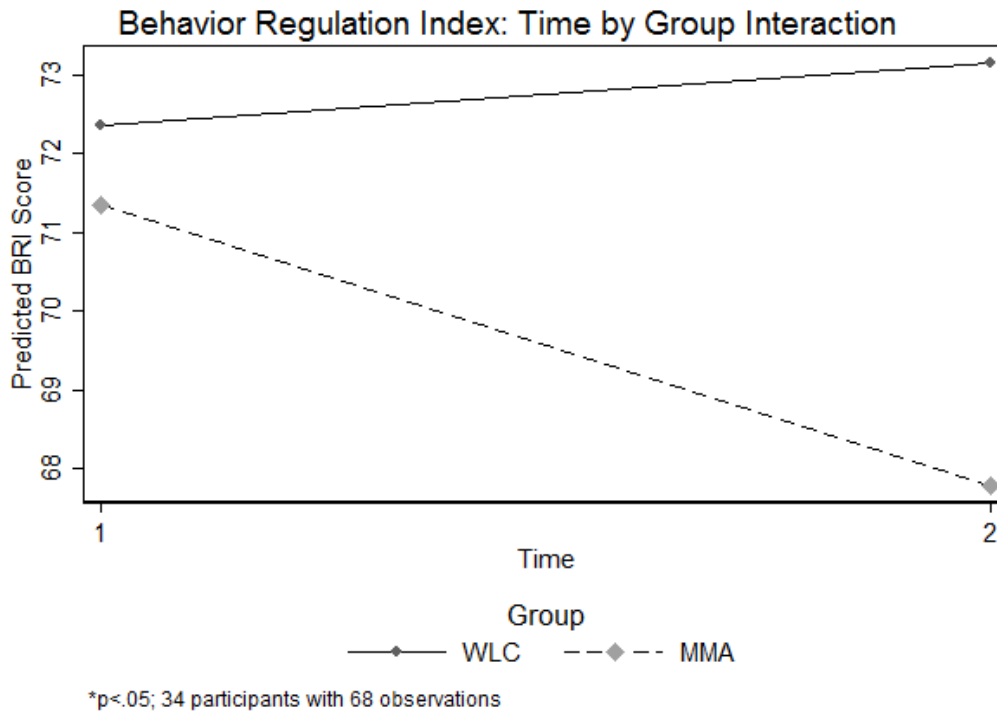


Figure 4. Time by group interaction on parent-reported BRIEF Behavior Regulation

Results also indicated no significant main effect of time ( $b = .18, p = .88$ ) and a significant interaction between group and predicted emotion regulation over time, such that the MMA group had 5.40 lower ERI score at post-test, as compared to the WLC group and controlling for pre-test scores, with a large effect size of  $d_{change} = -.88$  (Table 4; Figure 5).

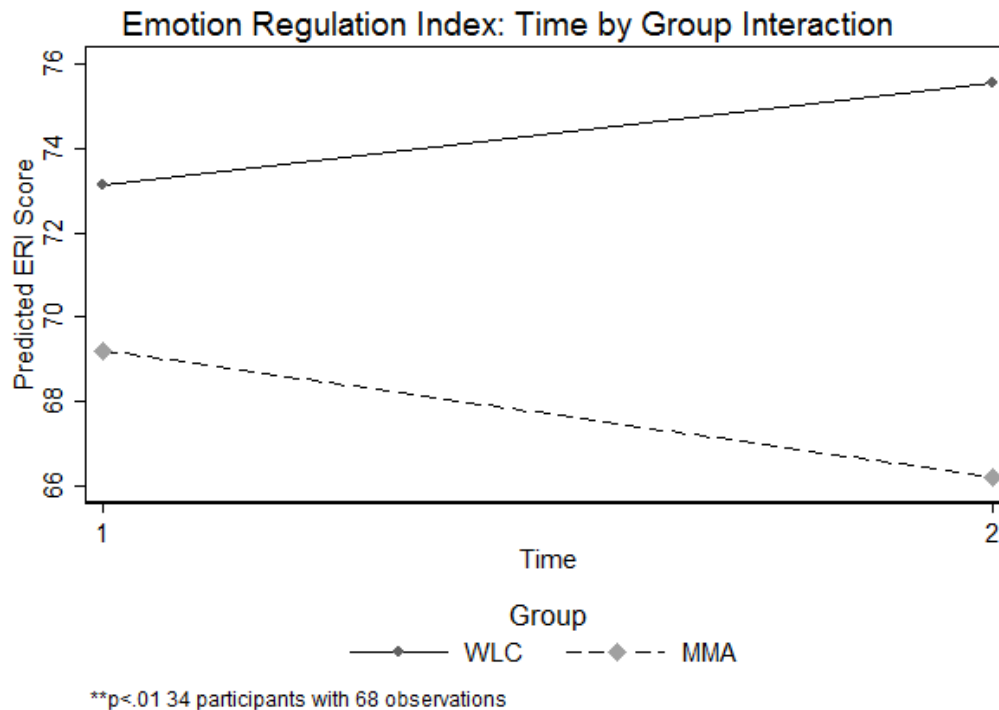


Figure 5. Time by group interaction on parent-reported BRIEF Emotion Regulation

No significant main effect of time or significant interaction between group and predicted cognitive regulation (CRI) (small to medium effect size of  $d_{change} = -.46$ ) over time was found. No significant main effect of time was found for global executive functioning ( $b = -.65, p = .51$ ). However, a significant interaction between group and predicted global executive functioning over time was found. The MMA group had 4.36 lower GEC score at post-test, as compared to the WLC group and controlling for pre-test scores, with a large effect size of  $d_{change} = -.81$  (Table 4; Figure 6).

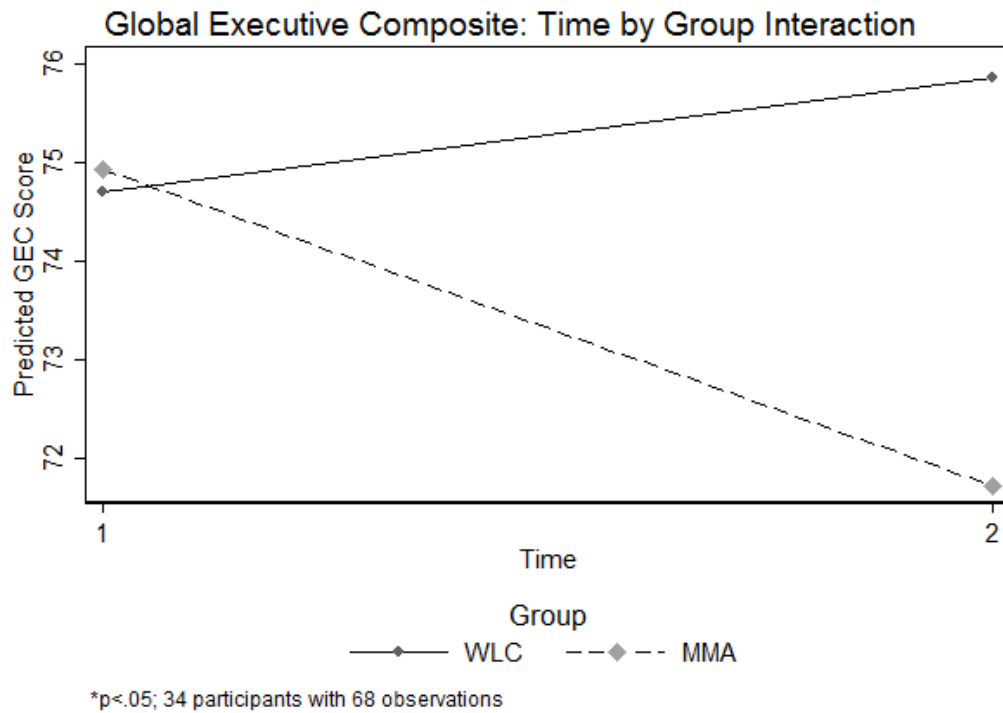


Figure 6. Time by group interaction on parent-reported BRIEF Global Executive Functioning Composite

For the analyses examining child performance on the Hearts & Flowers test, no significant main effect of time was found for predicted accuracy in the congruent block ( $b = -.45$ ,  $p = .84$ ). However, a significant interaction between group and predicted accuracy in the congruent block over time was found. The MMA group had an accuracy score that was 9.77% higher than the WLC group at post-test controlling for pre-test scores, with a large effect size of  $d_{change} = .83$  (Table 4; Figure 7).

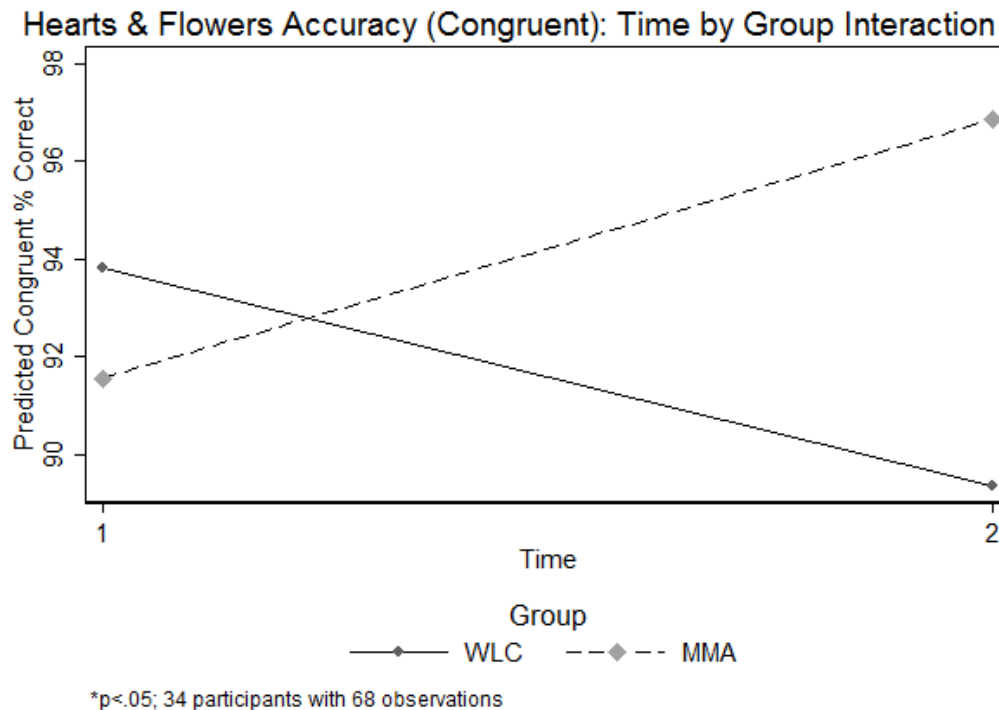


Figure 7. Time by group interaction on Hearts & Flowers accuracy (congruent block)

A significant main effect of time ( $b = 9.72, p = .00$ ), but no significant interaction of group and time was found for accuracy in the incongruent condition (large effect size of  $d_{change} = 2.17$ ). A significant main effect of time was found for accuracy in the mixed block ( $b = 4.52, p = .01$ ). In addition, a significant interaction between group and predicted accuracy in the mixed block over time was also found. The MMA group had an accuracy score that was 9.58% higher than the WLC group at post-test controlling for pre-test scores, with a large effect size of  $d_{change} = 1.01$  (Table 4; Figure 8).

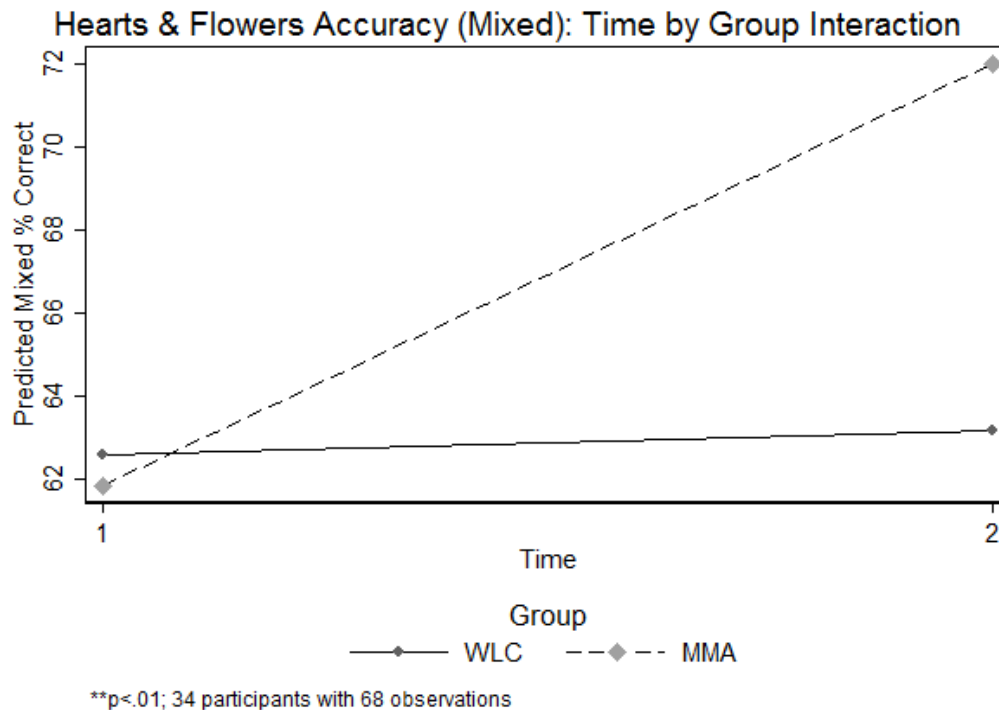


Figure 8. Time by group interaction on Hearts & Flowers accuracy (mixed block)

For response time across all three blocks, no significant main effects of time (congruent:  $b = -32.78, p = .30$ ; incongruent:  $b = -10.40, p = .71$ ; mixed:  $b = 7.22, p = .79$ ) were found. No significant group by time interactions were found; effect sizes ranged from small to medium ( $d_{change} = .06$  to  $-.56$ ). The hypothesis for Specific Aim 2, that executive functioning would be higher at post-test for the MMA group compared to the WLC, was supported for parent reports of executive functioning on the BRIEF, and partially-supported for the accuracy, but not for response times, on the Hearts & Flowers test.

### Within-group Correlation Analyses for MMA Group

Specific Aim 3, to examine within-group associations between intervention dosage and dilution, and post-test social and executive functioning, was examined using Spearman correlation analyses. As shown in Table 5, only variables from the Hearts & Flowers test were

significantly associated with intervention dosage and dilution. Greater intervention dosage was positively correlated with more accuracy in the congruent block, in the direction of more minutes and greater percentage correct. Greater intervention dosage was also negatively correlated with faster response time in the incongruent and mixed blocks (marginal), in the direction of more intervention minutes and lower response time. In addition, greater intervention dilution was negatively correlated with less accuracy in the incongruent and mixed blocks, such that more delay days was linked to a lower percentage of correct responses. The hypothesis for Specific Aim 3 was partially supported. Performance accuracy when participants were relying on their core EFs (i.e., working memory, behavioral inhibition, and cognitive flexibility) was higher when participants received more minutes of intervention within a more condensed period of time.

Table 5. Spearman correlation analyses of associations between indicators of fidelity and post-test outcomes for participants in the MMA group ( $n = 14$ )

Post-Test Study Variables	Minutes of intervention received	Days delay between pre- and post-test
Social Skills Improvement System (SSIS) <sup>1</sup>		
Social Skills	.13	.06
Problem Behaviors	-.01	.25
Social Interaction Task <sup>2</sup>		
Positive	.13	-.07
Low-Level	-.00	-.21
Executive Function: Behavior Rating Inventory (BRIEF) <sup>1</sup>		
Behavior Regulation	-.14	.30
Emotion Regulation	-.24	.13
Cognitive Regulation	.12	.41
Global Executive Functioning Composite	.07	.41
Executive Function: Hearts & Flowers Test <sup>2</sup>		
Accuracy (% correct)		
Congruent block	.61*	.28
Incongruent block	.04	-.58*
Mixed block	.03	-.59*
Response Time ( $ms^3$ )		
Congruent block	-.41	-.25
Incongruent block	-.50†	-.19
Mixed block	-.47†	.01

Notes. <sup>1</sup> Parent report measures. <sup>2</sup> Lab-based assessments. <sup>3</sup>  $ms$  = milliseconds.  
 † $p < .10$ . \* $p < .05$ .



## **Discussion**

ASD is a life-long challenge (Piven, Harper, Palmer, & Arndt, 1996): Children with ASD grow up to become adults with ASD, but optimal outcomes are possible (Fein et al., 2013). Interventions should be implemented to better prepare all children with ASD with functional skills for daily living. Intervention studies have found that social and executive functions (EFs) are malleable and can be enhanced with effortful practice. However, whereas there are many programs and classes in the community marketed towards families with ASD, only a handful is empirically-supported. The aims of the present study were to evaluate the effectiveness of a mixed martial arts (MMA) intervention on social and executive functioning in school-aged children with ASD.

The current multi-method study is novel in its examination of both social and cognitive domains of functioning in children with ASD and its investigation of both improvements in functioning and lessening of deficits. The study is noteworthy for its rigorous implementation of a MMA intervention in collaboration with a community-based martial arts studio. Results from each of the study hypotheses are discussed below.

### **Martial Arts Training and Social Functioning**

Hypothesis 1 regarding intervention group and social functioning was supported only for parent-reports of social functioning in the domains of social skills and problem behaviors. As expected, the supported findings indicated that martial arts training increased parental reports of social skills and decreased their reports of problematic social behaviors. The association with social skills had the second largest effect size (using the d-index change score) in the study. Past research has found that social skills interventions usually rely on an adult to prompt the performance of social behaviors and these behaviors are reinforced not with enjoyment in the

interaction, but with extrinsic rewards (Reichow & Volkmar, 2010), which limit the frequency of skill use when extrinsic rewards are not provided. The modeling and imitation of social behaviors by adults are useful during early childhood (Strain & Schwartz, 2001), but adults are less useful for assisting in the teaching of advanced social skills for interactions in middle-childhood. Social skills training with an overreliance on adult models has also demonstrated limited generalizability of skills when the adult is removed from the context (Rogers, 2000). The present study moved away from the adult-centered approach to improving social skills, and instead relied more heavily on a peer-facilitated approach with only limited adult-mediation. The apparent success of our mostly peer-based intervention is consistent with prior studies of the learning of complex social skills and like these studies (Bass & Mulick 2007; DiSalvo & Oswald, 2002), has the benefit of being generalizable to naturalistic settings with peers.

To date, there is only one other study that has used martial arts to target social dysfunction. Movahedi and colleagues (2013) found a decrease in problem behaviors after children with ASD received Kata training, a martial art that is similar to MMA in that it can consist of complex multi-step sequences, and can be practiced solo or in pairs. Consistent with Movahedi and colleagues (2013), the present study found a decrease in problem behaviors following the MMA intervention. In fact, the findings with the problem behaviors score had the largest effect size (using the d-index change score) of the social variables. Because parents were not blind to the condition in which their child was assigned, reports of better social skills and lessened problem behaviors might have been inflated. The results of the present study replicated the findings reported by Movahedi and colleagues' on social dysfunction, and extended it by also measuring and finding an improvement in social skills.

Movahedi and colleagues (2013) suggested that the mechanism of the observed effect was neurochemical change resulting from physical activity, though they (and I) did not measure neurochemical states, nor did either study include a comparison group of children enrolled in non-martial arts sports program. Movahedi and colleagues recommended that martial arts be used to assuage social dysfunction, and implied that practicing martial arts is no different than other physical activities. The authors also suggested that social dysfunction decreased after Kata training because the class included other children and adult instructors in attendance, which created a cohesive community that allowed for more opportunities to practice social skills. Under this rationale, any physical activity that gathers children with ASD and adult-facilitators should decrease social dysfunction.

In the present study's MMA intervention, participants engaged in dynamic interactions with other children in the class through the practicing of the MMA techniques. Children formed dyads and took turns "drilling", or practicing repetitiously, the demonstrated technique while facing one another. Like Kata, the movements were slow, controlled, and focused on form and rhythm of the technique; children learned about their movements and, unique to the current study, also the movements of their partners. The dynamic interaction of "partner-drilling" in the context of martial arts is comparable to engaging in a dance with a partner. Although the present study did not isolate which aspects of the intervention were responsible for the improvement in parent-reported social skills, partner-drilling in martial arts requires the use and practice of social skills that are critical in all interpersonal interactions: eye contact, verbal communication, and non-verbal communication (e.g., gestures). Partner-drilling appears to provide unique opportunities to develop more complex social skills, like social turn-taking.

Other social skills that were distinct in the present intervention were rapport building between partners, acquisition of skills in one partner-context (e.g., using punching mitts), generalization to another context (e.g., partner drilling), and receiving feedback from a peer. Whereas other martial arts interventions have relied on having children practice techniques in front of a mirror, mimic the movements of the adult instructor while he/she is standing beside the child, or use of hand-over-hand strategies (where the adult places their hands over that of the child and performs the technique for them), partner-drilling in the context of MMA engages not only basic social skills like eye contact, but the complex social skills described as well.

Unique and pivotal to the present study was the inclusion of the TD peer buddies. In past martial arts intervention studies, children rarely engaged in partner-drilling, and if they did, they only did so with an adult instructor. One of the limitations of Movahedi and colleagues' (2013) study was that they did not differentiate between the roles of peers with ASD and the adult instructors. A strength of the current study was the TD peer buddy system which allowed for children with ASD to be partnered with an expert peer. Consistent with Vygotsky's theory of social development (1978), the "more knowledgeable other" (in this case, the expert TD peer buddy) has a better understanding or higher ability than the learner (the inexperienced child with ASD). The more knowledgeable TD peer then scaffolds the learner through shared experiences together, and the learner is supported to achieve the new skills that he/she would not have been able to obtain alone. Although adult instructors and facilitators were available to demonstrate the techniques and facilitate interaction between children with ASD and TD peer buddies, the role of the TD peer buddies as the knowledgeable peer was crucial to the deliverance of the social skills portion of the intervention. TD peer buddies were experts in not only typical social behaviors, but because they were students in the TD MMA Kids classes, they also were experts in the

martial arts techniques. The inclusion of the TD peer experts may have driven the increase in social skills and decrease in problem behaviors in the participants with ASD. This implication is consistent with past work utilizing a peer-mediated intervention (Laushey & Heflin, 2000), which found that children with ASD increased social skills when learning from TD peers; social skills were then generalized to another setting. The current study extends the literature by including school-aged children with ASD. Further research is needed, however, to isolate the components of the MMA intervention to determine whether partner-drilling, the inclusion of TD peers, or some other aspects were most responsible for the observed effects.

Although Hypothesis 1 was supported by both scales on the parent-reported SSIS, it was not confirmed by the results from the lab-based social interaction task. This lack of significance was not expected. The social interaction task consisted of the two children planning and collaborating to complete the Pep Board activity, which entailed attaching colored Velcro-backed blocks onto a picture affixed with Velcro. Possibly, the social collaboration component on the Pep Board activity was too difficult for the children with ASD to complete without adult support. During the 15-minute task, many of children chose to work independently or to not partake in the activity at all rather than engage in planning and collaboration with their partner, even though they were instructed by the researcher to do so (Gelb & Jacobson 1988; Pepitone, 1980). The group means in Table 2 show there were more low-level (e.g., looking, functional communication to fulfill own needs with no social intent) social interactions than positive ones. Bauminger's (2002) coding scheme was designed for coding the social behaviors of children with high-functioning autism (HFA); it was borrowed to code social behaviors in the present study. In her sample of children with HFA, the verbal IQ averaged 84.87 compared to a lower verbal IQ of 79.24 in the present study. In addition, all children in Bauminger's (2002) sample

had a verbal IQ above 69, whereas the lowest verbal IQ for the present study was 45. Nearly 27% of my overall sample had a verbal IQ below 69. Because my study included children with lower verbal abilities, the coding scheme may not have been appropriate for coding social behaviors. Future work could include only children with HFA, or develop a coding scheme that would be more appropriate for children with ASD with lower verbal abilities.

In addition, the coding scheme used to code the videos in the present study was designed by Bauminger (2002) for live coding of naturalistic observations (e.g., recess, snack time) of TD and ASD pre-adolescents and adolescents; it was not designed to be used with the Pep Board activity, and not for a task in which the two children are strangers prior to the joint activity. A future study using this coding scheme could better adhere to observing children in naturalistic contexts as Bauminger intended. One way to do this would be to code the children in settings such as interacting with siblings at home or interacting with peers at school. Another option would be to adapt her coding scheme to accommodate a lab setting and delayed coding.

The Pep Board activity has been used in previous studies with TD children to encourage collaboration and interdependence rather than competitiveness, and therefore was expected to encourage the children with ASD in the present study to work together. Possibly, children with ASD had an overreliance on co-regulation with an adult facilitator, and therefore had difficulty interacting with other children when not prompted. In the future, perhaps a task that includes more detailed instructions and more facilitation from the researcher throughout the task would elicit more social interaction between the two participants in the dyad. Future work should move beyond coding only for frequency and also code for the duration and the quality of these social nuances (e.g., include duration and quality of eye contact).

## **Martial Arts Training and Executive Functioning**

Hypothesis 2 regarding intervention group and executive functioning was supported for both the parent-report and lab-based assessments of executive functioning. As expected, the findings overall indicated that martial arts training increased executive functioning in children with ASD. For the Hearts & Flowers test, all three core domains of executive functioning (i.e., working memory, behavioral inhibition, and cognitive flexibility) improved. Because the accuracy findings with the congruent block (i.e., working memory only) and mixed block (i.e., all three EFs: working memory, behavioral inhibition, and cognitive flexibility) were significant, but the incongruent block (i.e., both working memory and behavioral inhibition) was not, the results suggest that behavioral inhibition was the least improved of the three EFs.

The findings from the parent-reported BRIEF suggest that the EFs acquired in the context of the MMA intervention were generalized to contexts observable by parents. Of the three subscales, Behavior Regulation Index (BRI), Emotion Regulation Index (ERI), and Cognitive Regulation Index (CRI), emotion regulation had the largest effect size (using the d-index change score). Lakes & Hoyts (2004) found that self-regulation was improved after martial arts training in TD children. Consistent with their study, the present study had significant findings with behavior and emotion regulation, which are components of self-regulation. Cognitive regulation was not found to be significant; this was unexpected. The MMA intervention challenged and strengthened the behavior and emotion regulation domains, but likely did not provide sufficient opportunities to challenge cognitive regulation, which included subcomponents such as planning and organizing. Future research should examine which specific components of cognitive regulation can be feasibly targeted by martial arts training.

The present study's findings that martial arts training improves EFs such as behavioral inhibition are consistent with and expand on the findings reported by a previous study linking martial arts with decreased stereotypic behaviors among children with ASD (Bahrami et al., 2012); they also support the improved self-control findings of Chan and colleagues (2013). To extend upon Chan and colleagues' (2013) study, the current study measured multiple components of EFs using parent-report and an objective measure of executive functioning. The findings from the objective measure of executive functioning suggest that cognitive flexibility and working memory are also challenged and worked during martial arts training. Because EFs are multiple interrelated functions, this study highlights the importance of addressing multiple components of EFs.

Unique to the present intervention was the decision to utilize a MMA curriculum rather than only one type of martial art style. In this way, participants were provided with a variety of tools that not only adapted to their individual abilities, but were flexibly applied and generalized to different contexts. As evidenced by the parent-reports on the BRIEF, EFs gained in the context of MMA training were generalized by the children to contexts outside of the martial arts class, including at home and school.

The suggested mechanism behind the effectiveness of the MMA intervention was not only the variety of techniques, but also the physical activity incorporated into each class and the increasing complexity over the course of the intervention. Based on the findings from past literature, these specific intervention components appear to map onto the gains in specific EFs outcomes, although further research with a larger sample is needed to isolate these components to determine which specific aspects of the MMA intervention were responsible for the observed improvements in EFs.



### **Indicators of Fidelity and Study Outcomes at Post-test**

Hypothesis 3, that more minutes of intervention dosage and fewer days of intervention dilution would be correlated with better social and executive functioning scores at post-test within the MMA group, was partially supported. More intervention dosage was positively associated with higher accuracy for the congruent block in the Hearts & Flowers test, but not for the other two blocks. More minutes of intervention (i.e. dosage) was associated with higher accuracy in the congruent block perhaps because only working memory was required to complete the task. On the other hand, the incongruent block changed the rule (i.e., “When you see the Flower, press the button on the *other* side.”) and accommodating this rule required both working memory and behavioral inhibition to adapt and apply the new rule. The mixed block was the most difficult because it combined both rules in the same block, and required the active use of all three core EFs. It is possible that the acquired dosage in the present study was sufficient to improve accuracy in the congruent block, but not yet sufficient to impact the more difficult blocks. Perhaps longer training in martial arts could further improve EFs to increase accuracy in these blocks.

More number of days between pre- and post-test (i.e., intervention dilution, or days delay between test sessions) was significantly associated with less accuracy in the incongruent and mixed blocks. Because the incongruent and mixed blocks required more EF-use, the effects of the martial arts intervention appeared to be sensitive to the effects of time. That is, the more time between sessions and the longer time taken to complete the expected number of sessions, the less robust the effects of the martial arts intervention on EFs. These results suggest the importance of consistent and regular martial arts training to strengthen EFs for more cognitively challenging tasks that require the active use of the core EFs. Future research should further

examine this relationship to determine the minimum and optimum amount of training required to maintain long-term benefits.

### **Study Limitations**

The main limitation of the present study was the sample size, which limited power to find small or moderate effects. Sample size constrained the ability to control for demographic variables that differed between the intervention and wait list groups. However, only child gender was significantly different between the two groups. Despite random assignment, the MMA group was composed entirely of boys, whereas the WLC group had six girls. Additional analyses were conducted removing the six girls from the WLC group, so that there were 14 boys in each of the MMA and WLC groups (total  $n = 28$ ). The results omitting girls were robust and consistent with the reported results that included girls; the findings omitting girls remained significant with the exception of the behavioral regulation index on the BRIEF, which became marginal. Although we maintained these effects with a boys-only sample, future research should aim to equalize the number of girls and boys in each group. The overall preponderance of boys was not surprising given that ASD affects more boys than girls, and because martial arts is stereotypically an activity that tends to attract more boys than girls. Moving forward, the local MMA program will continue to encourage more enrollment of girls with ASD in the program. More girls in the program would increase the diversity of the martial arts class and provide participants with more opportunities to generalize their learned skills across different partners. Subsequent analyses with a larger sample size should also control for child intellectual functioning, which was heterogeneous in the present study.

Participating in the study was time intensive; families were asked to attend the MMA class two times per week for a minimum of 3 months. Busy family lives made it difficult for

children to complete the classes within the anticipated window. Specifically, fidelity analyses revealed that participants missed more sessions than was intended, and as a result, children took more days to obtain the dosage than was intended at design. Families raising children with ASD tend to center their lives around the child with ASD; time demands for child care and therapy (including transporting the child to appointments, juggling different types of therapies) impact the entire family unit (Myers, Mackintosh, & Goin-Kochel, 2009). A possible solution to this problem in the future would be to offer a greater number of MMA classes throughout the week to accommodate to families' schedules. Longitudinal follow-up of study participants would be useful to see whether the significant benefits to social skills and executive functioning endure.

An additional limitation was in the social interaction task. The lab-based assessment of social functioning had missing data, which may have contributed to the non-significant findings with those analyses. Also, the duration of the entire task was 15 minutes, but each child was only allotted 5 minutes to be the leader (10 minutes total of semi-structured interaction with the peer); the other 5 minutes were for unstructured rapport-building and for researcher instruction. In the future, this interaction could be further analyzed by only coding the interactions that occurred in the 10 minutes of semi-structured interaction with the peer.

Further research should include a comparison group of children with ASD who were enrolled in non-martial arts sports (e.g., basketball, baseball, soccer). For example, a group of children with ASD who participated in a team sports activity would help tease out whether organized physical activity with peers are just as important as mixed martial arts for social and executive functioning. Ideally, an alternative sports program would be comparable to the MMA intervention in terms of frequency, duration, and coverage (i.e., dose). Different sports certainly still have the potential to be cognitively complex and challenge EFs, but children would need to

be able to work together in the group setting. Because martial arts typically involve dyads rather than interaction in a group, addressing these social and executive challenges in children with ASD is more feasible in martial arts than in sports. If sports organizations plan to target social skills, they could plan more one-to-one interactions between children with ASD and TD peers. To better support the development of EFs, the different sports drills could include a component that increased in difficulty and complexity over time and ensure that this component is being addressed even in the group setting (i.e., that each child practices the increasingly difficult drills). Future research also is needed to further isolate which parts of the intervention accounted for the observed improvements, and whether these components can also be mapped onto sports. For example, Diamond and Lee (2011) reviewed a variety of activities, such as mindfulness and yoga, as possible alternative activities that pick up on the complexity of martial arts and its meditative elements.

The final limitation was that the parents in the study were not blind to the condition their child was assigned, so reporter bias is possible on the parent-report measures. Parents may have been inclined to report improvement due to their direct knowledge of their child's participation. However, pre- and post-test assessments were at minimum 3 months apart, which may have lessened the likelihood that parents remembered their previous responses. In addition, the objective measure of executive functioning, the Hearts & Flowers test, yielded significant findings, corroborating the parent reports of executive functioning.

### **Study Strengths**

Strengths of the study include random assignment to group, independence and reliability of the social observation task coders, blindness of the coders to participatory or waitlist group, and, within the MMA classes, blindness of the instructors and TD peer buddies to study

participants. Another strength of the intervention program was that the families did not pay for the classes. The MMA classes were funded by the academy owner, and the instructors who volunteered to teach the classes were not financially compensated.

Another strength is the use of multiple methods of parent-report and lab-based child assessments. Additionally, the sample was economically and ethnically diverse, and diverse in terms of child intellectual functioning and autism symptom severity. Instead of screening for only high-functioning children, we included somewhat lower-functioning children as well. Future research with a larger sample should examine if the intervention differentially affects children with ASD of varying functioning levels, and the magnitude of these possible effects. In one respect, higher functioning children may benefit more from the scaffolding because they have better verbal comprehension, but on the other hand, lower-functioning children may have more room for improvement.

For the social interaction task, having an unknown peer removed the confound of familiarity, and having random selection of each leader decreased the possibility of order effects. Another strength of the study was that we collected qualitative reports from parents about their opinions about the intervention. However, we did not ask the children with ASD or their TD peers what they thought about the classes. In addition to gathering qualitative feedback from parents, future work should also ask TD peer buddies and the children with ASD about their experiences. Both groups of children may benefit from the opportunities to interaction around MMA. Research by Campbell (2006) found that TD children who interact with children with ASD become more empathetic and motivated to continue their interactions with children with ASD, which also benefits the children with ASD.

## **Conclusions and Significance**

A MMA intervention program was implemented with school-aged children with ASD, and improvements were found on an objective measure of executive functioning and parent-reports of social and executive functioning, although the limitations of the study need to be considered. The next steps would be to further adapt the program based on the findings, and replicate it with the suggested improvements to study design. Parents of the MMA group were asked to provide optional, anonymous, and open-ended feedback about the program; parents lauded the patience, encouragement, and expertise of the well-trained instructors, the tolerance and kindness of the peer buddies, the emphasis on discipline and respect, and the safe space provided by the class community overall (for open-ended parent feedback, see Appendix F).

The theoretical and applied implications of the present study are expected to have relevance for the field of autism intervention research and for the autism community. On a theoretical level, the present study supplements the current literature on the malleability of EFs among children with ASD. The practice of MMA is a feasible way to improve executive functioning in school-aged children with ASD, and targeting EFs has implications for academic achievement, individual well-being, and overall health. The study also builds upon and informs intervention studies that utilize peer mediation to bolster social skills; key elements unique to the MMA intervention included partner drilling with TD peer buddies who facilitated the social interaction and modeled social behaviors.

On an applied level, the present study is the first to our knowledge to use a multi-method approach to examine various domains of outcomes of a MMA intervention in a sample of children with ASD. Whereas there are numerous recreational programs available to children with ASD that claim to be adaptive and inclusive, few programs provide empirical evidence to

support their claims. Furthermore, the martial arts academy that collaborated with the study has agreed to hold weekly classes based on the intervention curriculum designed for this study following the conclusion of this project, at no cost to the families. This commitment will ensure that children with ASD in the local community will continue to reap the benefits of the program, increase their individual functioning and perhaps their long-term well-being, with the opportunity to build long-lasting friendships based on a mutual love of martial arts.

## References

- Achenbach, T. M., & Rescorla, L. A. (2001). *Manual for the ASEBA School-Age Forms & Profiles*. Burlington, VT: University of Vermont, Research Center for Children, Youth, and Families.
- Adolphs, R., Baron-Cohen, S., & Tranel, D. (2002). Impaired recognition of social emotions following amygdala damage. *Journal of Cognitive Neuroscience, 14*, 1264-1274.
- Agam, Y., Joseph, R. M., Barton, J. J. S., & Manoach, D. S. (2010). Reduced cognitive control of response inhibition by the anterior cingulate cortex in autism spectrum disorders. *Neuroimage, 52*, 336–347.
- American Psychiatric Association. (2013). *Diagnostic and statistical manual* (5<sup>th</sup> ed.). Washington, DC: Author.
- Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8*, 71–82.
- Bahrami, F., Movahedi, A., Marandi, S. M., & Abedi, A. (2012). Kata techniques training consistently decreases stereotypy in children with autism spectrum disorder. *Research in Developmental Disabilities, 33*, 1183-1193.
- Barker, E. T., Hartley, S. L., & Seltzer, M. M. (2011). Trajectories of emotional well-being in mothers of adolescents and adults with autism. *Developmental Psychology 47*, 551–561.
- Baron-Cohen, S. (1988). Social and pragmatic deficits in autism: cognitive or affective? *Journal of Autism and Developmental Disorders, 18*, 379-402.
- Baron-Cohen, S. (1997). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: MIT press.
- Baron-Cohen, S. (2001). Theory of mind in normal development and autism. *Prisme, 34*, 174-



183.

- Baron-Cohen, S., Ring, H. A., Bullmore, E. T., Wheelwright, S., Ashwin, C., & Williams, S. C. R. (2000). The amygdala theory of autism. *Neuroscience & Biobehavioral Reviews*, *24*, 355-364.
- Baron-Cohen, S., Ring, H. A., Wheelwright, S., Bullmore, E. T., Brammer, M. J., Simmons, A., ... & Williams, S. C. R. (1999). Social intelligence in the normal and autistic brain: an fMRI study. *European Journal of Neuroscience*, *11*, 1891-1898.
- Barry, T. D., Klinger, L. G., Lee, J. M., Palardy, N., Gilmore, T., & Bodin, S. D. (2003). Examining the effectiveness of an outpatient clinic-based social skills group for high-functioning children with autism. *Journal of Autism and Developmental Disorders*, *33*, 685-701.
- Bass, J. D., & Mulick, J. A. (2007). Social play skill enhancement of children with autism using peers and siblings as therapists. *Psychology in the Schools*, *44*, 727-735.
- Bauminger, N. (2002). The facilitation of social-emotional understanding and social interaction in high-functioning children with autism: Intervention outcomes. *Journal of Autism and Developmental Disorders*, *32*, 283-298.
- Bell, A., Palace, K., Allen, M., & Nelson, R. (2016). Using martial arts to address social and behavioral functioning in children and adolescents with Autism Spectrum Disorder. *Therapeutic Recreation Journal*, *50*, 176-180.
- Bennetto, L., Pennington, B. F., & Rogers, S. J. (1996). Intact and impaired memory functions in autism. *Child Development*, *67*, 1816-1835.
- Best, J. R. (2010). Effects of physical activity on children's executive function: contributions of experimental research on aerobic exercise. *Developmental Review*, *30*, 331-551.

- Billstedt, E., Gillberg, I. C., & Gillberg, C. (2011). Aspects of quality of life in adults diagnosed with autism in childhood: A population-based study. *Autism, 15*, 7-20.
- Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., & Carmody, J., (2004). Mindfulness: A proposed operational definition. *Clinical Psychology: Science and Practice, 11*, 230–241.
- Blumenthal, J. A., Babyak, M. A., O'Connor, C., Keteyian, S., Landzberg, J., Howlett, J., ... & Whellan, D. J. (2012). Effects of exercise training on depressive symptoms in patients with chronic heart failure: the HF-ACTION randomized trial. *Journal of the American Medical Association, 308*, 465-474.
- Boe, E. E., Bobbitt, S. A., & Cook, L. H. (1997). Whither didst thou go? Retention, reassignment, migration, and attrition of special and general education teachers from a national perspective. *The Journal of Special Education, 30*, 371–389.
- Boyd, B. A., McBee, M., Holtzclaw, T., Baranek, G. T., & Bodfish, J. W. (2009). Relationships among repetitive behaviors, sensory features, and executive functions in high functioning autism. *Research in Autism Spectrum Disorders, 3*, 959–966.
- Brooks, R., & Meltzoff, A. N. (2002). The importance of eyes: How infants interpret adult looking behavior. *Developmental Psychology, 38*, 958–966.
- Brothers, L. (1990). The neural basis of primate social communication. *Motivation and Emotion, 14*, 81-91.
- Budde, H., Voelcker-Rehage, C., Pietraßyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience Letters, 441*, 219-223.
- Buescher, A. V., Cidav, Z., Knapp, M., & Mandell, D. S. (2014). Costs of autism spectrum

- disorders in the United Kingdom and the United States. *The Journal of the American Medical Association Pediatrics*, 168, 721-728.
- Campbell, J. M. (2006). Changing children's attitudes toward autism: A process of persuasive communication. *Journal of Developmental and Physical Disabilities*, 18, 251-272.
- Carlson, C. R., & Hoyle, R. H. (1993). Efficacy of abbreviated progressive muscle relaxation training: a quantitative review of behavioral medicine research. *Journal of Consulting and Clinical Psychology*, 61, 1059-1067.
- Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development*, 72, 1032-1053.
- Carrington, S. J., & Bailey, A. J. (2009). Are there theory of mind regions in the brain? A review of the neuroimaging literature. *Human Brain Mapping*, 30, 2313-2335.
- Carroll, C., Patterson, M., Wood, S., Booth, A., Rick, J., & Balain, S. (2007). A conceptual framework for implementation fidelity. *Implementation Science*, 2, 40-48.
- Centers for Disease Control and Prevention. (2016). *Autism spectrum disorder data and statistics*. Retrieved November 17, 2016, from <http://www.cdc.gov/ncbddd/autism/data.html>
- Champagne, F. A., & Curley, J. P. (2005). How social experiences influence the brain. *Current Opinion in Neurobiology*, 15, 704-709.
- Chan, A. S., Han, Y. M. Y., Leung, W. W. M., Leung, C., Wong, V. C. N., & Cheung, M. C. (2011). Abnormalities in the anterior cingulate cortex associated with attentional and inhibitory control deficits: a neurophysiological study on children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, 5, 254-266.
- Chan, A. S., Sze, S. L., Siu, N. Y., Lau, E. M., & Cheung, M. C. (2013). A Chinese mind-body

- exercise improves self-control of children with autism: a randomized controlled trial. *PLoS One*, 8, e68184.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Cohen, N. J., Gotlieb, H., Kershner, J., & Wehrspann, W. (1985). Concurrent validity of the internalizing and externalizing patterns of the Achenbach Child Behavior Checklist. *Journal of Consulting and Clinical Psychology*, 53, 724–728.
- Constantino, J. N. (2012). *Social Responsiveness Scale Second Edition*, Torrance, CA: Western Psychological Services.
- Cools, R., Clark, L., Owen, A. M., & Robbins, T. W. (2002). Defining the neural mechanisms of probabilistic reversal learning using event-related functional magnetic resonance imaging. *Journal of Neuroscience*, 22, 4563–4567.
- Courchesne, E., & Pierce, K. (2005). Brain overgrowth in autism during a critical time in development: Implications for frontal pyramidal neuron and interneuron development and connectivity. *International Journal of Developmental Neuroscience*, 23, 153–170.
- Crane, J. D., MacNeil, L. G., & Tarnopolsky, M. A. (2013). Long-term aerobic exercise is associated with greater muscle strength throughout the life span. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 68, 631-638.
- Cunningham, A. B. (2012). Measuring change in social interaction skills of young children with autism. *Journal of Autism and Developmental Disorders*, 42, 593-605.
- Daniels, A. M., Rosenberg, R. E., Anderson, C., Law, J. K., Marvin, A. R., & Law, P. A. (2012). Verification of parent-report of child autism spectrum disorder diagnosis to a web-based autism registry. *Journal of Autism and Developmental Disorders*, 42, 257-265.

- Dattilo, J., & Kleiber, D. A. (2002). Self-determination and enjoyment in therapeutic recreation. In D. Austin, J. Dattilo, & B. McCormick (Eds.), *Conceptual Foundations of Therapeutic Recreation* (73-92).
- Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*, 2037-2078.
- Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., & Naglieri, J. A. (2011). Exercise improves executive function and achievement and alters brain activation in overweight children: A randomized, controlled trial. *Health Psychology*, *30*, 91–98.
- Dawson, G., Meltzoff, A., Osterling, J., Rinaldi, J., & Brown, E. (1998). Children with autism fail to orient to naturally occurring social stimuli. *Journal of Autism and Developmental Disorders*, *28*, 479-485.
- Dawson, G., Munson, J., Estes, A., Osterling, J., McPartland, J., Toth, K., ... & Abbott, R. (2002). Neurocognitive function and joint attention ability in young children with autism spectrum disorder versus developmental delay. *Child Development*, *73*, 345–358.
- DeRosier, M. E., Swick, D. C., Davis, N. O., McMillen, J. S., & Matthews, R. (2011). The efficacy of a social skills group intervention for improving social behaviors in children with high functioning autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *41*, 1033-1043.
- Diamond, A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Development*, *71*, 44-56.
- Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood:

- Cognitive functions, anatomy and biochemistry. *Principles of Frontal Lobe Function*, 466–503.
- Diamond, A. (2012). Activities and programs that improve children’s executive functions. *Current Directions in Psychological Science*, 21, 335-341.
- Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, 64, 135-168.
- Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science*, 318, 1387-1388.
- Diamond, A., & Lee, K. (2011). Interventions Shown to Aid Executive Function Development in Children 4 to 12 Years Old. *Science*, 333, 959-964.
- DiSalvo, C. A., & Oswald, D. P. (2002). Peer-mediated interventions to increase the social interaction of children with autism consideration of peer expectancies. *Focus on Autism and Other Developmental Disabilities*, 17, 198-207.
- Dumas, J. E., Lynch, A. M., Laughlin, J. E., Smith, E. P., & Prinz, R. J. (2001). Promoting intervention fidelity: Conceptual issues, methods, and preliminary results from the Early Alliance prevention trial. *American Journal of Preventive Medicine*, 20, 38-47.
- Epp, K. M. (2008). Outcome-based evaluation of a social skills program using art therapy and group therapy for children on the autism spectrum. *Children and Schools*, 30, 27-36.
- Estes, A., Olson, E., Sullivan, K., Greenson, J., Winter, J., Dawson, G., & Munson, J. (2013). Parenting-related stress and psychological distress in mothers of toddlers with autism spectrum disorders. *Brain and Development*, 35, 133-138.
- Fein, D., Barton, M., Eigsti, I. M., Kelley, E., Naigles, L., Schultz, R. T., ... & Troyb, E. (2013). Optimal outcome in individuals with a history of autism. *Journal of Child Psychology and Psychiatry*, 54, 195-205.

- Flook, L., Smalley, S. L., Kitil, J. M., Galla, B. M., Kaiser-Greenland, S., Locke, J., & Kasari, C. (2010). Effects of mindful awareness practices on executive functions in elementary school children. *Journal of Applied School Psychology, 26*, 70–95.
- Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development, 10*, 483-527.
- Gallegos-Carrillo, K., García-Peña, C., Mudgal, J., Romero, X., Durán-Arenas, L., & Salmerón, J. (2012). Role of depressive symptoms and comorbid chronic disease on health-related quality of life among community-dwelling older adults. *Journal of Psychosomatic Research, 66*, 127-135.
- Garcia-Villamizar, D. A., & Dattillo, J. (2010). Effects of a leisure program on quality of life and stress of individuals with ASD. *Journal of Intellectual Disability Research, 54*, 611-619.
- Garfinkle, A. N., & Schwartz, I. S. (2002). Increasing social interactions in children with autism and other developmental disabilities in inclusive preschool classrooms. *Topics in Early Childhood Special Education, 22*, 26-38.
- Garrison-Harrell, L., Kamps, D., & Kravitz, T. (1997). The effects of peer networks on social-communicative behaviors for students with autism. *Focus on Autism and Other Developmental Disabilities, 12*, 241–254.
- Gelb, R., & Jacobson, J. L. (1988). Popular and unpopular children's interactions during cooperative and competitive peer group activities. *Journal of Abnormal Child Psychology, 16*, 247-261.
- Gersten, R., Keating, T., Yovanoff, P., & Harniss, M. K. (2001). Working in special education: factors that enhance special educators' intent to stay. *Exceptional Children, 67*, 549–567.
- Geurts, H. M., de Vries, M., & van den Bergh, S. F. (2014). Executive functioning theory and

- autism. In *Handbook of executive functioning* (121-141). New York: Springer.
- Gilbert, S. J., Bird, G., Brindley, R., Frith, C. D., & Burgess, P. W. (2008). Atypical recruitment of medial prefrontal cortex in autism spectrum disorders: An fMRI study of two executive function tasks. *Neuropsychologia*, *46*, 2281–2291.
- Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). Test review behavior rating inventory of executive function. *Child Neuropsychology*, *6*, 235-238.
- Goldberg, W. A., Thorsen, K. L., Osann, K., & Spence, M. A. (2008). Use of home videotapes to confirm parental reports of regression in autism. *Journal of Autism and Developmental Disorders*, *38*, 1136-1146.
- Grant, D. A., & Berg, E. A. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card - sorting problem. *Journal of Experimental Psychology*, *38*, 404 – 411.
- Gresham, F. M., & Elliott, S. N. (1990). *Social skills rating system*. Minneapolis, MN: NCS Pearson.
- Gresham, F. M., & Elliott, S. N. (2008). *Social skills improvement system rating scales manual*. Minneapolis, MN: NCS Pearson.
- Gresham, F. M., Elliott, S. N., Vance, M. J., & Cook, C. R. (2011). Comparability of the social skills rating system to the social skills improvement system: Content and psychometric comparisons across elementary and secondary age levels. *School Psychology Quarterly*, *26*, 27-44.
- Haith, M. M., Bergman, T., & Moore, M. (1977). Eye contact and face scanning in early infancy. *Science*, *198*, 853-855.
- Happé, F. G. (1994). An advanced test of theory of mind: Understanding of story characters'



- thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders*, 24, 129-154.
- Happé, F. & Frith, U. (1996). The neuropsychology of autism. *Brain*, 119, 1377-1400.
- Haring, T. G., & Breen, C. G. (1992). A peer-mediated social network intervention to enhance the social integration of persons with moderate and severe disabilities. *Journal of Applied Behavior Analysis*, 25, 319–333
- Hastings, R. P. & Brown, T. (2002). Behavior problems of children with autism, parental self-efficacy, and mental health. *American Journal on Mental Retardation*, 107, 222-232.
- Hauck, M., Fein, D., Waterhouse, L., & Feinstein, C. (1995). Social initiations by autistic children to adults and other children. *Journal of Autism and Developmental Disorders*, 25, 579–595.
- Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2002). Human neural systems for face recognition and social communication. *Biological Psychiatry*, 51, 59-67.
- Hendry, A., Jones, E. J., & Charman, T. (2016). Executive function in the first three years of life: Precursors, predictors and patterns. *Developmental Review*, 42, 1-33.
- Hertz-Lazarowitz, R., Kagan, S., Sharan, S., Slavin, R., & Webb, C. (Eds.). (2013). *Learning to cooperate, cooperating to learn*. Springer Science & Business Media.
- Hill, E. (2004). Executive dysfunction in autism. *Cognitive Science*, 8, 26-32.
- Hillman, C. H., Pontifex, M. B., Raine, L. B., Castelli, D. M., ... & Kramer, A. F. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience*, 159, 1044–1054.
- Hochhauser, M., & Engel-Yeger, B. (2010). Sensory processing abilities and their relation to

- participation in leisure activities among children with high-functioning autism spectrum disorder (HFASD). *Research in Autism Spectrum Disorders*, 4, 746-754
- Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, 12, F1-F7.
- Hughes, C., & Ensor, R. (2007). Executive function and theory of mind: Predictive relations from ages 2 to 4. *Developmental Psychology*, 43, 1447-1459.
- Hunnius, S., & Geuze, R. H. (2004). Developmental changes in visual scanning of dynamic faces and abstract stimuli in infants: A longitudinal study. *Infancy*, 6, 231–255.
- Ichikawa, H., Kanazawa, S., & Yamaguchi, M. K. (2011). The movement of internal facial features elicits 7 to 8-month-old infants' preference for face patterns. *Infant and Child Development*, 20, 464-474.
- Jansiewicz, E. M., Goldberg, M. C., Newschaffer, C. J., Denckla, M. B., Landa, R., & Mostofsky, S. H. (2006). Motor signs distinguish children with high functioning autism and Asperger's syndrome from controls. *Journal of Autism and Developmental Disorders*, 36, 613.
- Jarbrink, K. (2007). The economic consequences of autistic spectrum disorder among children in a Swedish municipality. *Autism*, 11, 453-463.
- Jarrold, C., Boucher, J., & Smith, P. K. (1996). Generativity deficits in pretend play in autism. *British Journal of Developmental Psychology*, 14, 275–300.
- Jennett, H., Harris, S., & Mesibov, G. (2003). Commitment to philosophy, teacher efficacy, and burnout among teachers of children with autism. *Journal of Autism and Developmental Disorders*, 33, 583-593.
- Johnson, M. H., Dziurawiec, S., Ellis, H., & Morton, J. (1991). Newborns' preferential tracking

- of face-like stimuli and its subsequent decline. *Cognition*, *40*, 1-19.
- Joseph, R. M., & Tager-Flusberg, H. (2004). The relationship between theory of mind and executive functions to symptom type and autism severity in children with autism. *Development and Psychopathology*, *16*, 137–155.
- Just, M. A., Cherkassky, V. L., Keller, T. A., & Minshew, N. J. (2004). Cortical activation and synchronization during sentence comprehension in high-functioning autism: Evidence of under connectivity. *Brain*, *127*, 1811-1821.
- Kamijo, K., Pontifex, M. B., O’Leary, K. C., Scudder, M. R., Wu, C. T., & Hillman, C. H. (2011). The effects of an afterschool physical activity program on working memory in preadolescent children. *Developmental Science*, *14*, 1046–1058.
- Kamps, D. M., Kravits, T., Lopez, A. G., Kemmerer, K., Potucek, J., & Harrell, L. G. (1998). What do the peers think? Social validity of peer-mediated programs. *Education and Treatment of Children*, 107-134.
- Kamps, D. M., Leonard, B. R., Vernon, S., Dugan, E. P., Delquadri, J. C., Gershon, B., ... & Folk, L. (1992). Teaching social skills to students with autism to increase peer interactions in an integrated first-grade classroom. *Journal of Applied Behavior Analysis*, *25*, 281–288.
- Kamps, D. M., Potucek, J., Lopez, A. G., Kravits, T., & Kemmerer, K. (1997). The use of peer networks across multiple settings to improve social interaction for students with autism. *Journal of Behavioral Education*, *7*, 335–357.
- Kana, R. K., Keller, T. A., Minshew, N. J., & Just, M. A. (2007). Inhibitory control in high functioning autism: Decreased activation and underconnectivity in inhibition networks. *Biological Psychiatry*, *62*, 198-206.

- Kennedy, C. H., & Shukla, S. (1995). Social interaction research for people with autism as a set of past, current, and emerging propositions. *Behavioral Disorders, 21*, 21-35.
- Key, A. P., Stone, W., & Williams, S. M. (2009). What do infants see in faces? ERP evidence of different roles of eyes and mouth for face perception in 9-month-old infants. *Infant and Child Development, 18*, 149-162.
- Kim, S. H., & Lord, C. (2010). Restricted and repetitive behaviors in toddlers and preschoolers with autism spectrum disorders based on the autism diagnostic observation schedule (ADOS). *Autism Research, 3*, 162-173.
- Klein, N., & Kemper, K. J. (2016). Integrative approaches to caring for children with autism. *Current Problems in Pediatric and Adolescent Health Care, 46*, 195-201.
- Klingberg, T., Fernell, E., Olesen, P., Johnson, M., Gustafsson, P., Dalhstrom, K., . . . & Westerberg, H. (2005). Computerized training of working memory in children with ADHD- a randomized, controlled, trial. *Journal of American Academy of Child and Adolescent Psychiatry, 44*, 177-186.
- Koning, C., & Magill-Evans, J. (2001). Social and language skills in adolescent boys with Asperger syndrome. *Autism, 5*, 23-36.
- Krech, D., Rosenzweig, M. R., & Bennett, E. L. (1966). Environmental impoverishment, social isolation and changes in brain chemistry and anatomy. *Physiology & Behavior, 1*, 99-104.
- Lakes, K. D., Bryars, T., Sirisinahal, S., Salim, N., Arastoo, S., Emmerson, N., ... & Kang, C. J. (2013). The Healthy for Life Taekwondo pilot study: A preliminary evaluation of effects on executive function and BMI, feasibility, and acceptability. *Mental Health and Physical Activity, 6*, 181-188.
- Lakes, K. D., & Hoyt, W. (2004). Promoting self-regulation through school-based martial arts

- training. *Applied Developmental Psychology*, 25, 283-302.
- Landa, R. J. (2005). Assessment of social communication skills in preschoolers. *Mental Retardation and Developmental Disabilities Research Reviews*, 11, 247–252.
- Laushey, K. M., & Heflin, L. J. (2000). Enhancing social skills of kindergarten children with autism through the training of multiple peers as tutors. *Journal of Autism and Related Disorders*, 30, 183-193.
- Lavelle, T., Weinstein, M. C., Newhouse, J. P., Munir, K., Kuhlthau, K. A., & Prosser, L. A. (2014). Economic Burden of Childhood Autism Spectrum Disorders. *Pediatrics*, 133, e520-e529.
- Lecavalier, L., Leone, S., & Wiltz, J. (2006). The impact of behavior problems on caregiver stress in young people with autism spectrum disorders. *Journal of Intellectual Disability Research*, 50, 172-183.
- Leigh, J. P., & Du, J. (2015). Brief report: Forecasting the economic burden of autism in 2015 and 2025 in the United States. *Journal of Autism and Developmental Disorders*, 45, 4135-4139.
- Lipsey, M. W., Puzio, K., Yun, C., Hebert, M. A., Steinka-Fry, K., Cole, M. W., ... & Busick, M. D. (2012). Translating the statistical representation of the effects of education interventions into more readily interpretable forms. *National Center for Special Education Research*.
- Lopez, B., Lincoln, A. J., Ozonoff, S., & Lai, Z. (2005). Examining the relationship between executive functions and restricted, repetitive symptoms of autistic disorder. *Journal of Autism and Developmental Disorders*, 35, 445–460.
- Lord, C., Risi, S., Lambrecht, L., Cook, E. J., Leventhal, B., DiLavore, P., ... & Rutter, M.

- (2000). The autism diagnostic observation schedule-generic: a standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders*, *30*, 205-223.
- Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S.L. (2012). *Autism Diagnostic Observation Schedule, (ADOS-2) Manual (Part 1): Modules 1-4*. Torrance, CA: Western Psychological Services.
- Lovaas, O. I. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of Consulting and Clinical Psychology*, *55*, 3-9.
- Lovaas, O. I., & Smith, T. (1989). A comprehensive behavioral theory of autistic children: Paradigm for research and treatment. *Journal of Behavioral Therapy and Experimental Psychiatry*, *20*, 17-29.
- Lovaas, O. I., & Smith, T. (2003). Early and intensive behavioral intervention in autism. In A. E. Kazdin & J. R. Weisz (Eds.), *Evidence-based psychotherapies for children and adolescents* (325-340). New York: Guilford Press.
- Luna, B., Minshew, N. J., Garver, K. E., Lazar, N. A., Thulborn, K. R., Eddy, W. F., & Sweeney, J. A. (2002). Neocortical system abnormalities in autism: An fMRI study of spatial working memory. *Neurology*, *59*, 834-840.
- Marcovitch, S., & Zelazo, P. D. (1999). The A-not-B error: Results from a logistic meta-analysis. *Child Development*, *70*, 1297-1313.
- Matson, J. L., Hattier, M. A., & Belva, B. (2012). Treating adaptive living skills of persons with autism using applied behavior analysis: A review. *Research in Autism Spectrum Disorders*, *6*, 271-276.
- Matson, J. L., & Minshawi, N. F. (2007). Functional assessment of challenging behavior:

- Toward a strategy for applied settings. *Research in Developmental Disabilities*, 28, 353-361.
- Matthews, N. L., Goldberg, W. A., & Lukowski, A. F. (2013). Theory of mind in children with autism spectrum disorder: do siblings matter? *Autism Research*, 6, 443–453.
- Miller, M., Iosif, A. M., Hill, M., Young, G. S., Schwichtenberg, A. J., & Ozonoff, S. (2017). Response to name in infants developing Autism Spectrum Disorder: A prospective study. *The Journal of Pediatrics*, 183, 141-146.
- Minshew, N. J., Turner, C. A., & Goldstein, G. (2005). The application of short forms of the Wechsler Intelligence scales in adults and children with high functioning autism. *Journal of Autism and Developmental Disorders*, 35, 45-52.
- McClure, S. M., York, M. K. P., & Montague, R. (2004). The neural substrates of reward processing in humans: the modern role of fMRI. *Neuroscientist*, 10, 260–268.
- Meltzoff, A. N. (2007). “Like me”: a foundation for social cognition. *Developmental Science*, 10, 126-134.
- Merin, N., Young, G. S., Ozonoff, S., & Rogers, S. J. (2006). Visual fixation patterns during reciprocal social interaction distinguish a subgroup of 9-month old infants at risk for autism from comparison infants. *Journal of Autism and Developmental Disorders*, 37, 108-121.
- Movahedi, A., Bahrami, F., Marandi, S. M., & Abedi, A. (2013). Improvement in social dysfunction of children with autism spectrum disorder following long term kata techniques training. *Research in Autism Spectrum Disorders*, 7, 1054–1061.
- Myers, B. J., Mackintosh, V. H., & Goin-Kochel, R. P. (2009). “My greatest joy and my greatest

- heart ache:” Parents’ own words on how having a child in the autism spectrum has affected their lives and their families’ lives. *Research in Autism Spectrum Disorders*, 3, 670-684.
- Nelson, C. (1987). The recognition of facial expressions in the first two years of life: mechanisms of development. *Child Development*, 58, 889–909.
- Odom, S. L., & Strain, P. S. (1984). Peer-mediated approaches to promoting children’s social interaction: A review. *American Journal of Orthopsychiatry*, 54, 544.
- Oord, V. D. S., Meulen, E. M., Prins, P. J. M., Oosterlaan, J., Buitelaar, J. K., & Emmelkamp, P. M. G. (2005). A psychometric evaluation of the social skills rating system in children with attention deficit hyperactivity disorder. *Behavior Research and Therapy*, 43, 733–746.
- Osterling, J. A., & Dawson, G. (1994). Early recognition of children with autism: A study of first birthday home videotapes. *Journal of Autism and Developmental Disorders*, 24, 247-257.
- Osterling, J. A., Dawson, G., & Munson, J. A. (2002). Early recognition of 1-year-old infants with autism spectrum disorder versus mental retardation. *Development and Psychopathology*, 14, 239-251.
- Owen-Deschryver, J. S., Carr, E. G., Cale, S. I., & Blakeley-Smith, A. (2008). Promoting social interactions between students with autism spectrum disorders and their peers in inclusive school settings. *Focus on Autism and Other Developmental Disabilities*, 23, 15-28.
- Owens, G., Granader, Y., Humphrey, A., & Baron-Cohen, S. (2008). LEGO therapy and the social use of language programme: An evaluation of two social skills interventions for children with high functioning autism and Asperger syndrome. *Journal of Autism and Developmental Disorders*, 38, 1944-1957.



- Ozonoff, S., Iosif, A. M., Baguio, F., Cook, I. C., Hill, M. M., Hutman, T., ... & Steinfeld, M. B. (2010). A prospective study of the emergence of early behavioral signs of autism. *Journal of the American Academy of Child & Adolescent Psychiatry, 49*, 256-266.
- Ozonoff, S., & Jensen, J. (1999). Specific executive function profiles in three neurodevelopmental disorders. *Journal of Autism and Developmental Disorders, 29*, 171-177.
- Ozonoff, S., & McEvoy, R. E. (1994). A longitudinal study of executive function and theory of mind development in autism. *Development and Psychopathology, 6*, 415-431.
- Ozonoff, S., & Miller, J. N. (1995). Teaching theory of mind: A new approach to social skills training for individuals with autism. *Journal of Autism and Developmental Disorders, 25*, 415-433.
- Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1991). Executive function deficits in high-functioning autistic children: relationship to theory of mind. *Journal of Child Psychology and Psychiatry, 32*, 1081-1105.
- Ozonoff, S., & Schetter, P. L. (2007). Executive dysfunction in autism spectrum disorders. *Executive function in education: From Theory to Practice*, 133-160.
- Ozonoff, S., & Strayer, D. (2001). Further evidence of intact working memory in autism. *Journal of Autism and Developmental Disorders, 31*, 257-263.
- Pan, C. Y. (2010). Effects of water exercise swimming program on aquatic skills and social behaviors in children with autism spectrum disorders. *Autism, 14*, 9-28.
- Pellicano, E. (2007). Links between theory of mind and executive function in young children with autism: Clues to developmental primacy. *Developmental Psychology, 43*, 974-990.

- Pellicano, E. (2010). The development of core cognitive skills in autism: A 3-year prospective study. *Child Development, 81*, 1400–1416.
- Pellicano, E. (2012). The development of executive function in autism. *Autism Research and Treatment, 1-8*.
- Pepitone, E. A. B. (Ed.). (1980). *Children in cooperation and competition: Toward a developmental social psychology*. Lexington books.
- Petrus, C., Adamson, S. R., Block, L., Einarson, S. J., Sharifnejad, M., & Harris, S. R. (2008). Effects of exercise interventions on stereotypic behaviours in children with autism spectrum disorder. *Physiotherapy Canada, 60*, 134–45.
- Piaget, J. (1954). *The Construction of Reality in the Child*. London: Routledge.
- Piaget, J. (1963). *The Origins of Intelligence in Children*. New York: W.W. Norton.
- Piaget, J. (1977). Problems of equilibration. In *Topics in cognitive development (3-13)*. Springer US.
- Piven, J., Harper, J., Palmer, P., & Arndt, S. (1996). Course of behavioral change in autism: A retrospective study of high-IQ adolescents and adults. *Journal of the American Academy of Child & Adolescent Psychiatry, 35*, 523-529.
- Rapin, I., & Katzman, R. (1998). Neurobiology of autism. *Annals of Neurology, 43*, 7–14.
- Rapoport, M., van Reekum, R., & Mayberg, H. (2000). The role of the cerebellum in cognition and behavior: a selective review. *Journal of Neuropsychiatry, 12*, 193–198.
- Reichow, B., & Volkmar, F. R. (2010). Social skills interventions for individuals with autism: Evaluation for evidence-based practices within a best evidence synthesis framework. *Journal of Autism and Developmental Disorders, 40*, 149–166.
- Reichow, B., Volkmar, F. R., & Cicchetti, D. V. (2008). Development of the evaluative method

- for evaluating and determining evidence-based practices in autism. *Journal of Autism and Developmental Disorders*, *38*, 1311–1319.
- Reznick, J. S., Morrow, J. D., Goldman, B. D., & Snyder, J. (2004). The onset of working memory in infants. *Infancy*, *6*, 145-154.
- Rogers, S. J. (2000). Interventions that facilitate socialization in children with autism. *Journal of Autism and Developmental Disorders*, *30*, 399–409.
- Rognmo, Ø., Moholdt, T., Bakken, H., Hole, T., Mølsted, P., Myhr, N. E., ... & Wisløff, U. (2012). Cardiovascular risk of high-versus moderate-intensity aerobic exercise in coronary heart disease patients. *Circulation*, *126*, 1436-1440.
- Rozanski, A. (2012). Exercise as Medical Treatment for Depression. *Journal of the American College of Cardiology*, *60*, 1064-1066.
- Rutter, M., Bailey, A., & Lord, C. (2003). *Social Communication Questionnaire (SCQ)*. Los Angeles, CA: Western Psychological Services.
- Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development of executive functioning and theory of mind: A comparison of Chinese and U.S. preschoolers. *Psychological Science*, *17*, 74–81.
- Sacrey, L. A. R., Zwaigenbaum, L., Bryson, S., Brian, J., Smith, I. M., Roberts, W., ... & Vaillancourt, T. (2015). Can parents' concerns predict autism spectrum disorder? A prospective study of high-risk siblings from 6 to 36 months of age. *Journal of the American Academy of Child & Adolescent Psychiatry*, *54*, 470-478.
- Sheridan, S. M., Bovaird, J. A., Glover, T. A., Garbacz, S. A., & Witte, A. (2012). A randomized trial examining the effects of conjoint behavioral consultation and the mediating role of the parent-teacher relationship. *School Psychology Review*, *41*, 23-46.

- Schipul, S. E., Williams, D. L., Keller, T. A., Minshew, N. J., & Just, M. A. (2012). Distinctive neural processes during learning in autism. *Cerebral Cortex*, *22*, 937-950.
- Schmahmann, J. D., & Sherman, J. C. (1998). The cerebellar cognitive affective syndrome. *Brain*, *121*, 561-579.
- Schmitz, N., Rubia, K., Daly, E., Smith, A., Williams, S., & Murphy, D. G. M. (2006). Neural correlates of executive function in autistic spectrum disorders. *Biological Psychiatry*, *59*, 7-16.
- Schmitz, O. S., Mcfadden, B. A., Golem, D. L., Pellegrino, J. K., Walker, A. J., Sanders, D. J., & Arent, S. M. (2017). The Effects of Exercise Dose on Stereotypical Behavior in Children with Autism. *Medicine and Science in Sports and Exercise*, *49*, 983-990.
- Schnorr, J. M. (1995). Teacher retention: A CSPD analysis and planning model. *Teacher Education and Special Education: The Journal of the Teacher Education Division of the Council for Exceptional Children*, *18*, 22-38.
- Schultz, R. T., Gauthier, I., Klin, A., Fulbright, R. K., Anderson, A. W., Volkmar, F., ... & Gore, J. C. (2000). Abnormal ventral temporal cortical activity during face discrimination among individuals with autism and Asperger syndrome. *Archives of General Psychiatry*, *57*, 331-340.
- Sharon, T., & DeLoache, J. S. (2003). The role of perseveration in children's symbolic understanding and skill. *Developmental Science*, *6*, 289-296.
- Smith, L. B., & Thelen, E. (2003). Development as a dynamic system. *Trends in Cognitive Sciences*, *7*, 343-348.
- South, M., Ozonoff, S., & McMahon, W. M. (2007). The relationship between executive

- functioning, central coherence, and repetitive behaviors in the high-functioning autism spectrum. *Autism, 11*, 437–451.
- StataCorp. 2017. *Stata Statistical Software: Release 14*. College Station, TX: StataCorp LP.
- Strain, P., & Schwartz, I. (2001). ABA and the development of meaningful social relations for young children with autism. *Focus on Autism and Other Developmental Disabilities, 16*, 120–128.
- Swift, D. L., Johannsen, N. M., Lavie, C. J., Earnest, C. P., & Church, T. S. (2014). The role of exercise and physical activity in weight loss and maintenance. *Progress in Cardiovascular Diseases, 56*, 441-447.
- Tenenbaum, E., Shah, R. J., Sobel, D. M., Malle, B. F., & Morgan, J. L. (2013). Increased focus on the mouth among infants in the first year of life: A longitudinal eye-tracking study. *Infancy, 18*, 534-553.
- Terpstra, A. H. M., Beynen, A. C., Everts, H., Kocsis, S., Katan, M. B., & Zock, L., (2002). The decrease in body fat in mice fed conjugated linoleic acid is due to increases in energy expenditure and energy loss in the excreta. *Journal of Nutrition, 132*, 940-945.
- Thelen, E. (1979). Rhythmical stereotypies in normal human infants. *Animal Behavior, 27*, 699-715.
- Thorell, L. B., Lindqvist, S., Bergman N. S., Bohlin, G. & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science, 12*, 106–113.
- Toal, F., Murphy, D. G., Murphy, K. C. (2005). Autistic-spectrum disorders: Lessons from neuroimaging. *The British Journal of Psychiatry, 187*, 395–397.
- Turner, M. (1999). Annotation: repetitive behavior in autism: A review of psychological

- research. *Journal of Child Psychology and Psychiatry*, 40, 839–849.
- U.S. Bureau of Labor Statistics. (2017). *Persons with a disability: Labor force characteristics summary*. Retrieved September 30, 2017, from <http://www.bls.gov/news.release/disabl.nr0.htm>
- U.S. Department of Health and Human Services. (2015). *A sex-specific dissection of autism genetics*. Retrieved September 30, 2017, from <https://iacc.hhs.gov/apps/portfolio-analysis-web-tool/project?projectId=3459&fy=2010>
- Vandell, D. L., Nenide, L., & Van Winkle, S. J. (2006). Peer relationships in early childhood. *Blackwell Handbook of Early Childhood Development*, 455-470.
- Virues-Ortega, J. (2010). Applied behavior analytic intervention for autism in early childhood: Meta-analysis, meta-regression and dose –response meta-analysis of multiple outcomes. *Clinical Psychology Review*, 30, 387–399.
- Vismara, L. A., & Rogers, S. J. (2010). Behavioral treatments in autism spectrum disorder: What do we know? *Annual Review of Clinical Psychology*, 6, 447-468.
- Vygotsky, L. (1978). Interaction between learning and development. *Readings on the Development of Children*, 23, 34-41.
- Walsh, R. (2011). Lifestyle and mental health. *American Psychologist*, 66, 579-592.
- Wechsler, D. (2011). *WASI-II: Wechsler abbreviated scale of intelligence*. Psychological Corporation.
- Werner, E., & Dawson, G. (2005). Validation of the phenomenon of autistic regression using home videotapes. *Archives of General Psychiatry*, 62, 889-895.
- Wetherby, A. M., Woods, J., Allen, L., Cleary, J., Dickinson, H., & Lord, C. (2004). Early

- indicators of autism spectrum disorders in the second year of life. *Journal of Autism and Developmental Disorders*, 34, 473-493.
- Whalen, C., & Schreibman, L. (2003). Joint attention training for children with autism using behavior modification procedures. *Journal of Child Psychology and Psychiatry*, 44, 456-468.
- Wolery M., & Garfinkle A. N. (2002). Measures in intervention research with young children who have autism. *Journal of Autism and Developmental Disorders*, 32, 463-478.
- Wright, A., & Diamond, A. (2014). An effect of inhibitory load in children while keeping working memory load constant. *Frontiers in Psychology*, 5, 1-9.
- Zelazo, P. D., & Müller, U. (2010). Executive function in typical and atypical development. *The Wiley-Blackwell Handbook of Childhood Cognitive Development, Second edition*, (ed U. Goswami), Wiley-Blackwell, Oxford, UK.
- Zelazo, P. D., Müller, U., Frye, D., & Marcovitch, S. (2003). The development of executive function in early childhood. *Monographs of the Society for Research in Child Development*, 68, i-151.
- Zwaigenbaum, L., Bryson, S., & Garon, N. (2013). Early identification of autism spectrum disorders. *Behavioural Brain Research*, 251, 133-146.
- Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neuroscience*, 23, 143-152.

## Appendix A

### Demographics and background information questionnaire

Has your child ever participated in any martial arts program? If yes, please describe: _____	Yes	No	If yes, for how long? Enter in months: _____	Is he/she currently participating? Yes / No
Has your child ever participated in any sports program? If yes, please describe: _____	Yes	No	If yes, for how long? Enter in months: _____	Is he/she currently participating? Yes / No If yes, please describe: _____

- 1) What is your relationship to the child who will be participating in this study?
- Mother
  - Father
  - Other (please specify: \_\_\_\_\_)

**Please answer the following questions about your child and family.**

- 2) Child's Birth Date (MM/DD/YYYY): \_\_\_\_\_
- 3) Child's Age (In Years): \_\_\_\_\_
- 4) Is your child a female or a male?
- Male
  - Female
- 5) Does your child have a current diagnosis (i.e., Autism Spectrum Disorder, Aspergers, ADHD, Down Syndrome, etc.)?
- Yes (Please explain/ list all): \_\_\_\_\_
  - No
- 6) Please describe your child's race/ethnicity.
- American Indian/ Alaskan Native
  - Asian/ Asian American
  - Black/ African American
  - Native Hawaiian/ Other Pacific Islander
  - White/ Caucasian
  - Other (Please specify: \_\_\_\_\_)
- 7) Please select your child's ethnicity:
- Hispanic or Latino
  - Not Hispanic or Latino
- 8) What is your current marital status?
- Married



- Not married/living together with partner
  - Separated/Divorced
  - Widowed
  - Single/Never married
- 9) Which parent does your child live with the majority of the time?
- Both parents
  - Mother
  - Father
  - Other caregiver (e.g., grandparent)
  - Shared custody (e.g., weekends)
- 10) Please select your child's MOTHER'S race/ethnicity.
- American Indian/ Alaskan Native
  - Asian/ Asian American
  - Black/ African American
  - Native Hawaiian/ Other Pacific Islander
  - White/ Caucasian
  - Other (Please specify: \_\_\_\_\_)
- 11) Highest level of school completed by mother:
- Less than high school
  - High school graduate or GED
  - Post high school certificate or specialized training
  - Community college (Associate's Degree)
  - Standard college or university graduation (Bachelor's Degree)
  - Graduate professional training (Graduate Degree)
- 12) Mother's employment (if unemployed, indicate "N/A"):
- Place of employment: \_\_\_\_\_
- Job Title: \_\_\_\_\_
- Major job duties/responsibilities: \_\_\_\_\_
- Usual number of paid work hours (per week): \_\_\_\_\_
- 13) Please select your child's FATHER'S race/ethnicity.
- American Indian/ Alaskan Native
  - Asian/ Asian American
  - Black/ African American
  - Native Hawaiian/ Other Pacific Islander
  - White/ Caucasian
  - Other (Please specify: \_\_\_\_\_)
- 14) Highest level of school completed by father:
- Less than high school
  - High school graduate or GED
  - Post high school certificate or specialized training
  - Community college (Associate's Degree)
  - Standard college or university graduation (Bachelor's Degree)
  - Graduate professional training (Graduate Degree)
- 15) Father's employment (if unemployed, indicate "N/A"):
- Place of employment: \_\_\_\_\_
- Job Title: \_\_\_\_\_

Major job duties/responsibilities: \_\_\_\_\_

Usual number of paid work hours (per week): \_\_\_\_\_

16) What is your yearly household income?

- \$0 - \$49,999
- \$50,000 – \$99,999
- \$100,000 – \$149,999
- \$150,000 - \$199,999
- \$200,000 - \$249,999
- \$250,000+

17) Please list information for your child’s siblings, starting with the OLDEST sibling (if no siblings, please click “>>” below to skip this section).

Sibling #	Sex		Date of Birth (MM/DD/YY )	Different Father?		Different Mother?		List any diagnoses, health, behavior, learning problems	Lives with your child?	
	M	F		Y	N	Y	N		Y	N
1	M	F		Y	N	Y	N		Y	N
2	M	F		Y	N	Y	N		Y	N
3	M	F		Y	N	Y	N		Y	N
4	M	F		Y	N	Y	N		Y	N
5	M	F		Y	N	Y	N		Y	N

18) Is your child currently, or were they ever, receiving therapy or intervention for autism related behaviors or symptoms?

- Yes
- No

19) Therapy Participation (please place check in appropriate boxes)

	Has your child ever received the following therapies?			How long? (in months)
	Currently receiving this	Previously received this, but no longer	Has never received this	
Applied Behavior Analysis				
Floortime				
Occupational				
Speech/Language				

Social Skills Training				
Psychotherapy (e.g., cognitive behavioral therapy)				
Other (please specify:_____)				

20) Prenatal/Birth History

Biological Mom age when child was born: \_\_\_\_\_

Biological Dad age when child was born: \_\_\_\_\_

Biological Mom total number of pregnancies: \_\_\_\_\_

Biological Mom total number of live births: \_\_\_\_\_

Biological Mom total number of miscarriages: \_\_\_\_\_

21)

	Yes/No		Were babies identical?		Select one:		
Was child product of a multiple birth?	Yes	No	Yes	No	Twin	Triplet	Quadruplet

22) Problems with labor or delivery?

Yes (please explain: \_\_\_\_\_)

No

23) Number of weeks when baby was born: \_\_\_\_\_

24) Were there newborn problems?

Yes (please explain: \_\_\_\_\_)

No

25) At what age (in months) did you first notice problems (developmental delays or differences) in:

Social development: \_\_\_\_\_

Speech and language: \_\_\_\_\_

Problem solving: \_\_\_\_\_

Behavior: \_\_\_\_\_

26) Does your child have any of the following? (select all that apply):

- Anxious or worries
- Unusual or excessive fears
- Short attention span
- Depression
- Hyperactivity
- Impulsive
- Obsessive-compulsive
- Defiant
- Aggressive
- Self-injury (head banging, biting, scratching, cutting, etc.)
- Hurting animals or other people
- Toileting issues, accidents

**Neurological history**

27) Does your child have any of the following (select all that apply):

- Tic disorder
- Tremors
- Hypotonia (low muscle tone/floppy)
- Hypertonia (tight muscle tone)
- ADHD
- Migraines/headaches
- Toe walking (after age 2 or persistent for more than 6 months)
- Numbness/tingling

28) Does your child have seizures

- Yes (please explain: \_\_\_\_\_)
- No

**29) Please indicate the educational program in which your child participated during his/her school\* years:**

**\*REGULAR school applies to public or private schools for children WITHOUT disabilities**

**\*SPECIAL school applies to any schools intended for children WITH disabilities**

Grade	Type of school		Type of class		Any special services		If yes to special services, what type?
	Regular	Special	Regular	Special	Yes	No	
Preschool (3-5yo)	Regular	Special	Regular	Special	Yes	No	
Kinder	Regular	Special	Regular	Special	Yes	No	
1 <sup>st</sup> grade	Regular	Special	Regular	Special	Yes	No	
2 <sup>nd</sup> grade	Regular	Special	Regular	Special	Yes	No	
3 <sup>rd</sup> grade	Regular	Special	Regular	Special	Yes	No	
4 <sup>th</sup> grade	Regular	Special	Regular	Special	Yes	No	
5 <sup>th</sup> grade	Regular	Special	Regular	Special	Yes	No	
6 <sup>th</sup> grade	Regular	Special	Regular	Special	Yes	No	

30) Is there anything else that you would like us to know about you, your child, or your family's medical, developmental, or background history that was not mentioned above?

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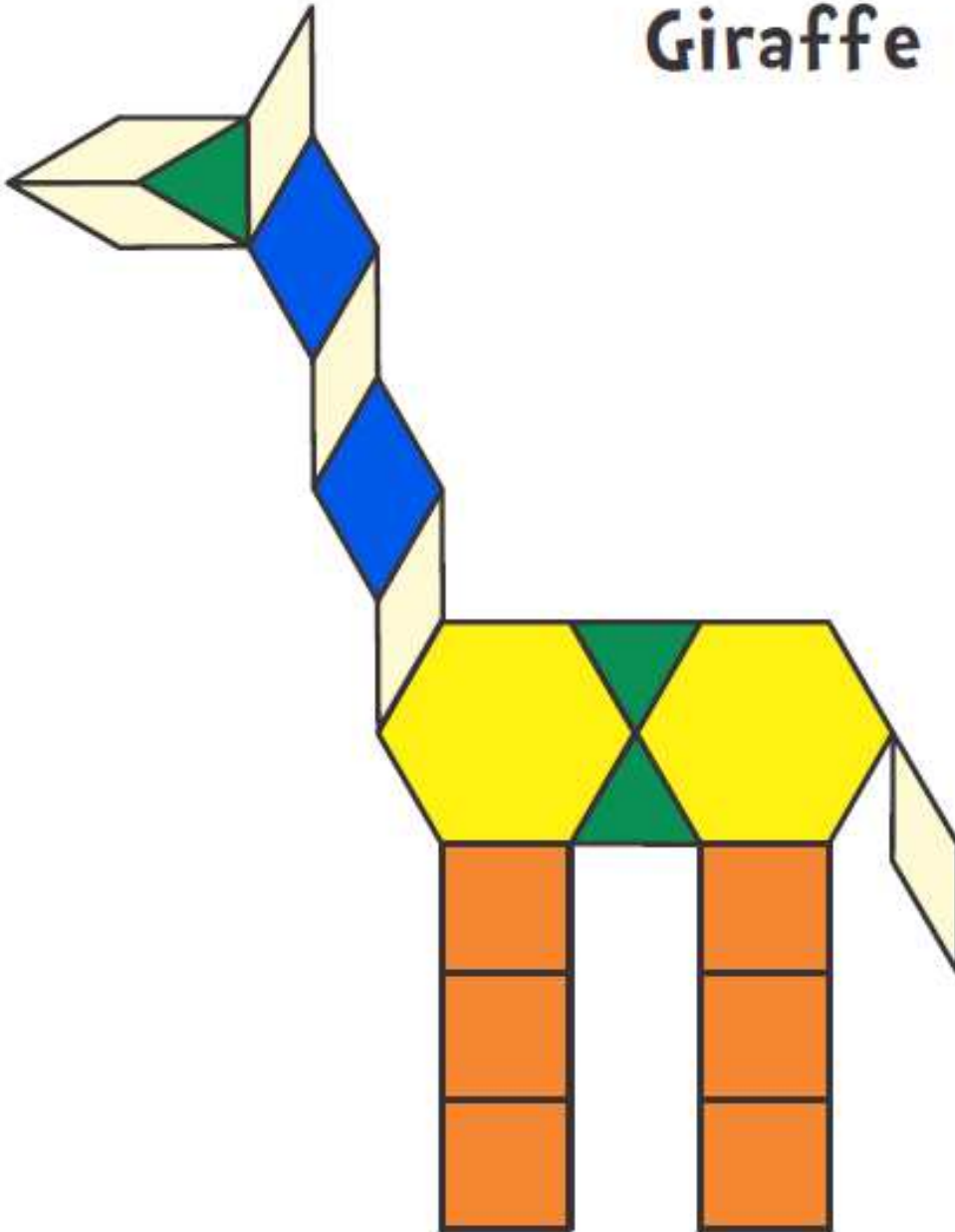


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**Appendix B**

**Sample of pattern board used in social interaction task**

**Giraffe**



## Appendix C

### Definitions of observed social behaviors used for coding social interaction task (Bauminger, 2002)

1. Social initiation: The child begins a new social sequence, distinguished from a continuation of a previous sequence by a change in activity.

2. Social response: The child responds verbally and/or nonverbally to social stimuli directed toward him/her by peers.

**3. Positive social interaction:** The child exhibits verbal and nonverbal social behaviors that lead to an effective social process with peers. Behaviors that serve to start or maintain social interaction.

- Eye contact—The child looks into the eyes of another child.
- Eye contact combined with smile—The child looks at and smiles toward another child.
- Smile with no eye contact—The child smiles at another child but does not look into the peer's eyes.
- Affection—The child expresses affection toward another child, either verbally (e.g., “You’re nice,” “I like you”) or nonverbally (e.g., hugs, touches).
- Sharing objects—The child offers his/her objects to another child or shares an object with another child.
- Sharing experience—The child tells about an experience to peers or asks them about their experiences (e.g., “What did you do over the weekend?”).
- Social communication—The child approaches another child with a social (rather than functional) intention (e.g., “Let’s play”).
- Talk that reflects an interest in another child—The child expresses an interest in another child’s hobbies (e.g., “What’s your favorite game/object?”), mood (e.g., “Are you sad?”), etc.
- Greeting—The child says hello to another child or replies appropriately to such a greeting.
- Giving help—The child offers help to another child.

**4. Negative social interaction:** The child exhibits unpleasant social behaviors that operate to stop or decrease the likelihood of the development of an adequate social interaction.

- Physical or verbal aggressiveness—The child behaves in malicious intrusive ways toward peers (e.g., yells, screams, makes fun of, hits, pushes, pinches, slaps).
- Temper tantrum—The child expresses anger in an extreme way (e.g., screams and shouts, hits other children, hits objects/walls, etc.).
- Teasing—The child tries to drag another child into a fight or conflict.
- Controlling—The child dominates other children without respecting their needs.
- Avoidance—The child avoids social overtures made toward him/her by peers.
- Looking away—The child actively avoids social contact by looking away from the initiator.

**5. Low-level interaction:** The child exhibits behaviors that indicate social intention, but with minimal social enactment, such as close proximity to children without initiating a positive social interaction. Also includes behaviors typical of the autistic syndrome (e.g., echolalia, idiosyncratic language).

- Looking—The child looks at the other child’s face or body, or child’s action, without establishing eye contact.
- Close proximity—The child stands in close proximity to another child (3 feet or less) but does not approach the peer.
- “Yes” and “no”—The child only nods his/her head for yes or shakes it for no.
- Imitation—The child imitates another child’s talk or activity.
- Idiosyncratic language—The child uses utterances with no clear meaning.
- Repetitive behavior—The child behaves in a repetitive manner with no clear communication intent, but with close proximity to another child.
- Functional communication—The child approaches or responds to another child with an intention to fulfill his/her own needs, and with no social intention (e.g., “It’s my turn on the computer now”).

## Appendix D

### Coding sheet used by observers of the social interaction task

<b>Time Interval</b> <i>(mm:ss – mm:ss)</i>	<b>Type of Behavior</b> <i>(Initiation, Response)</i>	<b>Valence of Interaction</b> <i>(Positive, Negative, Low)</i>	<b>Description of Behavior</b> <i>(see Bauminger, 2002, “Definitions of Observed Social Behaviors”)</i>
00:00 - 00:10			
00:10 - 00:20			
00:20 - 00:30			
00:30 - 00:40			
00:40 - 00:50			
00:50 - 01:00			
01:00 - 01:10			
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05:50 - 06:00			
06:00 - 06:10			



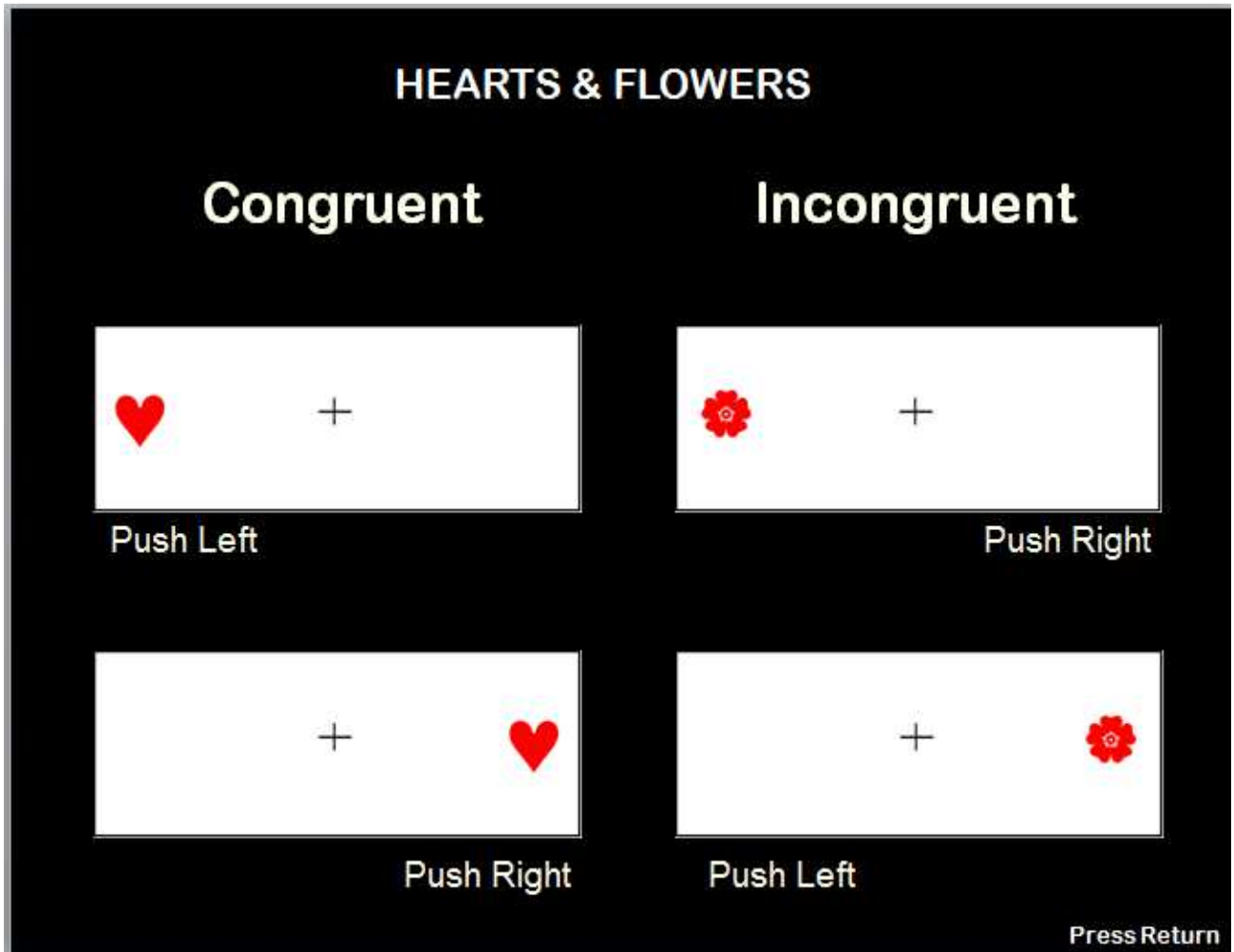
06:10 - 06:20			
06:20 - 06:30			
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14:00 - 14:10			
14:10 - 14:20			
14:20 - 14:30			
14:30 - 14:40			
14:40 - 14:50			
14:50 - 15:00			
<b>Totals:</b>	<b>Initiations:</b>	<b>Positive:</b>	
	<b>Responses:</b>	<b>Negative:</b>	
		<b>Low-level:</b>	
<b>Summary:</b>			
	<b>Initiations</b>	<b>Responses</b>	<b>Total</b>
<i>Positive</i>			
<i>Negative</i>			
<i>Low-level</i>			
<b>Total</b>			

## Appendix E

### Sample stimuli of the Hearts & Flowers test

(source: <http://www.devcogneuro.com/eftasks.html>)



## Appendix F

### Open-ended parent feedback

*Note: Responses have been edited for clarity and to omit identifying information.*

1) Please describe your child's experience with: **COACHES**

- I want to start by saying [this] program is amazing! My child has an overall mental delay and has many social and behavioral issues. The coaches have a very good understanding of each child's disability and works with them individually and in groups in a positive, structured manner.
- I am so grateful for this opportunity that my son can be a part of. Not only is this beneficial for my son but also therapeutic for me as a parent seeing him interact with other children and peers.
- [The] coach knows how to motivate my son out of his comfort zone in such a positive way that is fun and rewarding. [He] has a real understanding of my son's potential and knows exactly what social behaviors they need to work on.
- The coaches were very patient and tolerant and seem to have experience working with special needs children. They always made an effort to foster an inclusive environment and provided opportunities for the kiddos to join the activity.
- While there were accommodations made based on a child's capability, it did not limit my son's participation with the peer buddies. I believe this is what makes this type of program unique.
- [The head coach] worked great with the kids, I love how he always addressed them by first name and corrected them the same way. I think this was a great way to see how my child does around her peers outside of school with a sport/hobby. I'm so glad I chose to enter my child.
- [The head coach] is a great example of effective coaching. He balances discipline and kindness. He challenges them but never stops encouraging them along.
- My son respects and likes his coach very much and that helps him learn easier and train better. We are truly grateful for his time and patience.

2) Please describe your child's experience with: **PEER BUDDIES**

- I have so much respect for the peer buddies! As young as some of them are, they are so caring and have positive attitudes.
- One of the highlights of this program was the peer buddies. I was very impressed with the way they handled themselves and could tell they understood the important role they were taking on to make a difference in another child's life.
- From my personal experience, I witnessed many of the peer buddies go out of their way to engage with my son before and after the session (e.g., greeting him, making sure he had eye contact, etc.). Kudos to the peer buddies as well as their parents for allowing their kids to partake in this program without prejudice.
- I think the peers played a very important role in the class. They were amazing!
- We are involved with a lot of autism groups. It is nice to have my child interacting with typical kids. I think they challenge him and make him practice his

social skills more. The peers are really patient and nice to him.

- 3) Please describe your child's experience with: **PERSONAL GROWTH** since participating in the program
- Social growth, self-confidence, coordination.
  - Since participating in this program, we saw more personal growth in the areas of behavior and social interaction.
  - His listening skills and eye contact have improved a bit and he's engaging with us more.
  - She has been more on-task, confident, and respectful.
  - Improvement in coordination and balance, improved body control and listening skills. He also follows direction better too with less prompting. He has more self-confidence and interest in others.
  - He has gotten better at being frustrated when things are hard. There are less tantrums at home and school.
  - My child was able to stand up to a classmate that had been bullying him. Martial arts helped him be more confident and stand up for himself. I'm glad he won't be picked on anymore.
  - Less emotional. He doesn't get as upset about things that frustrated him before. He is also more coordinated.
- 4) Is there anything else that you'd like to share with us about the All Stars MMA Program and/or OC Kickboxing & Mixed Martial Arts? If so, please use the space below.
- This is a wonderful program and we are grateful to the coaches and peer buddies for their commitment and allowing our son to participate in an activity that he probably would not have a chance to elsewhere without judgment.
  - As a parent with a child on the spectrum who struggles daily to interact socially, even the smallest positive reaction was gratifying. We will never forget the day he "leap-frogged" independently and smiled while doing it.
  - Coaches are awesome and we absolutely love the welcoming environment!
  - Please keep it going! Our Kiddos will reap the most benefits the longer and more consistent they stay doing it.
  - We hope to stay in the program as long as it is running.
  - This program has truly made a positive impact on my son in such a short period so far. I would, and have recommended this program to family and friends with children and disabilities.