**Executive function as a mediator of gains in preschool early intervention**

**Applicants:** Allison Nahmias, MA, MEd, Doctoral Candidate, University of Pennsylvania
Benjamin Yerys, PhD, Center for Autism Research, Children's Hospital of Philadelphia

**Mentors and Mentor role:** This grant offers the unique opportunity to provide mentorship and training at two levels. The primary level is that Dr. Yerys will mentor Ms. Nahmias in executive function in young children with ASD in monthly meetings (more often as needed). At a secondary level the overall project PI, David Mandell, ScD will mentor Dr. Yerys (and Ms. Nahmias) in community-based intervention research and mediation/moderation analyses in monthly meetings (more often as needed). Thus, this project would advance the knowledge base of two junior scientists.

**Project description:** This large project proposal will enhance the "Which placement for which child?: Moderators of outcome in an early intervention system" study by including executive function as a potential mediator of cognitive outcomes of early intervention (EI). This ongoing 3-year Autism Speaks funded study will follow 300 preschoolers with ASD receiving EI in inclusion, mixed-disability (MD), or autism-only settings in Philadelphia for 9 months. Child characteristics (including cognitive, social, play and adaptive behavior skills) are measured through a combination of direct assessment, classroom observations, parent-report and teacher/EI provider report at entry to EI (T1) and 9 months later (T3). The type and quality of intervention are measured using direct observation once the child has been in a setting for four months (T2).

***Objectives of proposed study:*** To integrate direct assessment, a classroom observation, and teacher report of executive function in the "Which placement for which child?" study to explore the role of executive function skills as a mediator of social and cognitive gains by first examining if executive function skills improve from preschool EI and if changes in executive function predict social and cognitive outcomes.

Executive function refers to a set of abilities that regulates impulses and emotions and channels them into socially appropriate goal-directed behavior. Cognitive processes that comprise executive function include working memory, inhibition set-shifting/cognitive flexibility, and vigilance/sustained attention. Executive function can be broken down into 'cool' (emotion-independent; e.g., attention, working memory, and set-shifting) and 'hot' (emotion laden; e.g., emotion regulation) domains.[1,2] Children with ASD show a wide range of executive function skills during the preschool years.[3] The development of executive function skills is more strongly associated with academic readiness in Kindergarten than cognitive ability or entry-level reading and math skills.[4,5] Executive function also mediates gains in pre-academic skills for low-income preschoolers receiving early intervention services[6] and early executive function intervention predicts academic performance.[7] For preschoolers with ASD, executive function has been shown to predict social skills like joint attention and theory of mind[9].

Executive function skills can be intervened upon in different ways, and this may be reflected in the various active agents in EI for children with ASD. For example, autism-only EI programs may provide direct instruction in executive function through practice at sustained attention and training in multi-step directions (working memory). Inclusive EI programs may provide modeling of good executive function. Consistent with Vygotsky's notion of a "zone of proximal development," children learn executive function skills faster when they see another child who is just slightly better/faster at the skill then they are.[10] **This project aims to assess executive function skills in 100 preschoolers (~33 per EI placement) in Year 1 of the "Which intervention for which child?" study using a multi-modal battery to examine changes in and correlates of executive function skills.** The secondary aim is whether change in executive function mediates change in other domains of function (social and cognitive).

**Dependent variables (specific to this extension project, existing study measures not re-stated):**

- Direct assessment battery: This battery of 3 tasks will assess both hot and cool executive function and can be completed in ~5 minutes, to limit the additional burden to the child:
  1. The Spatial Reversal task[11] assesses flexibility and perseveration when learning a new rule, which is of interest due to the rigid behaviors and cognitions that often comprise repetitive behaviors in ASD.
  2. The Balance Beam task[12] asks children to walk a short line at increasingly slower speeds – which taps into 'cool' inhibition because there is no emotional component.
  3. The Tongue Task[12] has the child place an M&M on their tongue and withhold from eating it until cued by the examiner – which taps into 'hot' inhibition because there is an emotional component.
- Teacher report: will take ~10 minutes.
  1. The Behavior Rating Inventory of Executive Function-Preschool (BRIEF-P) assesses the teacher's per

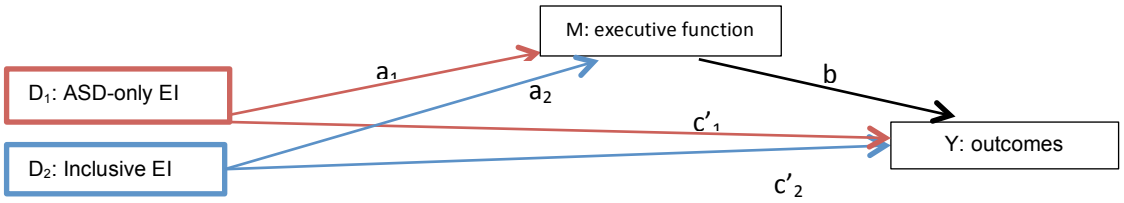
- Child observations: Observations will be added to the battery of observations conducted as part of the "Which intervention for which child?" study in order to streamline the data collection process:
  5. Observations of impulse control and attention to task during structured assessments[12]
  6. Observations of on-task/off-task behavior during typical intervention/classroom services[15]

We chose measures 1 and 4 because of their previous use with young children with ASD,[3,15] measures 2, 3, and 5 because they have been field-tested and validated in EI settings similar to those in the Philadelphia EI system,[6] and measure 6 because it has been used successfully in prior intervention studies in ASD.[16]

**Independent Variables:** Placement in preschool EI system: Autism-only, Mixed-disability, Inclusion

**Hypotheses and Analysis Plan:**
Prior to any analyses we will use Structural Equation Modeling (SEM) to extract a latent variable of executive function from all executive function measures to create a global composite. A social composite will combine existing study measures: the Social scales in the Social Skills Improvement System[17] and Adaptive Behavior Assessment System – 2nd Edition[18] (ABAS-2). The Early Learning Composite from the Mullen Scales of Early Learning[19] (MSEL) will comprise the cognitive composite.

*Hypothesis 1a:* Executive function skills will improve T1-2 and T1-3. Specifically, based on our prior research[20] Autism-only and Inclusion placements will lead to significantly greater change in executive function skills than the mixed-disability placement. We will use linear regressions with random effects for site and child (to account for correlated observations across time). We will test this hypothesis by modeling the main and interactive effects on outcome of placement type and executive function while controlling for baseline characteristics.
*Hypothesis 1b:* Greater executive function improvements will predict better social and cognitive outcomes. We will test the main and interactive effects on social and cognitive outcome of executive function and placement type while controlling for other baseline characteristics.
*(Exploratory) Hypothesis 2:* Gains in executive function between T1 and T2 will mediate the relationship between EI placement at Time 1 and cognitive and social gains at T3 controlling for baseline scores. We will test the following mediation model:




MD is the reference group for the model.

As recommended by Hayes and Preacher (2013)[21] the mediation model will be parameterized using the following equations: $M = i_1 + a_1 D_1 + a_2 D_2 + e_M$; $Y = i_2 + c'_1 D_1 + c'_2 D_2 + e_Y$
The model will be estimated simultaneously using SEM. We will use the asymmetric bootstrap confidence interval (CI) method for statistical inference about relative indirect effects of ASD-only EI vs. MD EI ($a_1b$) and Inclusive EI vs. MD EI ($a_2b$).

**Pitfalls and Next Steps:**
- Floor effects and poor reliability of performance based executive function tests: We will drop tests exhibiting floor effects, and teacher-report and classroom observations provide data without this limitation.
- Attrition: We'll provide paper, online, and phone options for completion of BRIEF-P for teachers.
- Executive function is not a mediator: In this case, we will explore executive function as a moderator.
- If initial mediation results are promising, we will apply for additional funding to increase enrollment.
- This project will test a potential mechanism by which cognitive gains occur as part of community-based EI. These results could inform the development of interventions for children with ASD (and new trials) that show more effective and sustainable treatment effects in community-based programs.

**Budget & Justification (Total=$23,164):**
- 100 kids @ 3 time points: BRIEF-P (300 @1.79= $537); Teacher time at T2=$5*300=$1500. Teachers currently receive reimbursement for completing forms at T1 and T3, so incentive is only for T2.
- Travel to/from preschools for observations/testing ($0.565/mile * 1000 miles=$565)
- RA time – (50% FTE*$32,960 plus 27.1% Fringe=$20,732) – In combination with Dr. Parish-Morris' project, this full-time RA (TBD) would increase operational efficiency and reduce classroom burden

References:


[1] Hongwanishkul D, Happaney KR, Lee WS, & Zelazo PD. Assessment of hot and cool executive function in young children: Age-related changes and individual differences. *Developmental neuropsychology*. 2005; 28(2): 617-644.

[2] Roiser JP, Sahakian BJ. Hot and cold cognition in depression. *CNS spectrums*. 2013; 18(03): 139-149.

[3] Yerys BE, Hepburn SL, Pennington BF, & Rogers SJ. Executive function in preschoolers with autism: Evidence consistent with a secondary deficit. *Journal of Autism and Developmental Disorders*. 2007; 37(6): 1068-1079.

[4] Blair C, & Razza RP. Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child development*. 2007; *78*(2): 647-663.

[5] McClelland MM, Morrison FJ, & Holmes DL. Children at risk for early academic problems: the role of learning-related social skills. Early Childhood Research Quarterly 2000; 1(3)5: 307–329.

[6] Raver CC, Jones, SM, Li-Grining, CP, et al. CSRP's impact on low-income preschoolers' pre-academic skills: Self-regulation as a mediating mechanism. *Child Development*. 2011; 82(1): 362–378

[7] Diamond A, Barnett WS, Thomas J, & Munro S. Preschool program improves cognitive control. *Science* 2007; 318(5855): 1387–1388.

[8] Griffith, E. M., Pennington, B. F., Wehner, E. A., & Rogers, S. J. (1999). Executive functions in young children with autism. *Child Development*, *70*(4), 817–832.

[9] Pellicano, E. (2012). The Development of Executive Function in Autism. *Autism Research and Treatment*, *2012*, e146132. doi:10.1155/2012/146132

[10] Vygotsky L. *Mind in Society: The Development of Higher Psychological Processes.* Cambridge, MA: Harvard University Press; 1978.

[11] Kaufman P, Leckman J, & Ort S. Delayed response performance in males with Fragile X. *Journal of Clinical and Experimental Neuropsychology*. 1989; 12: 69.

[12]Smith-Donald R, Raver CC, Hayes T, Richardson B. Preliminary construct and concurrent validity of the Pre-school Self-regulation Assessment (PSRA) for field-based research. *Early Childhood Research Quarterly*. 2007; 22:173-187.

[13] Gioia GA, Isquith PK, Retzlaff PD, & Espy KA (2002). Confirmatory factor analysis of the Behavior Rating Inventory of Executive Function (BRIEF) in a clinical sample. *Child Neuropsychology*. 2002; 8(4): 249-257.

[14] Barkley RA, Fischer M, Newby RF, & Breen, MJ. Development of a multimethod clinical protocol for assessing stimulant drug response in children with attention deficit disorder. *Journal of Clinical Child Psychology*. 1988; 17(1): 14-24.

[15] Smithson PE, Kenworthy L, Wills MC, Jarrett M, Atmore K, & Yerys BE. Real world executive control impairments in preschoolers with autism spectrum disorders. *Journal of Autism and Developmental Disorders*. 2013; 43(8): 1967-1975.

[16] Kenworthy L, Anthony LG, Naiman DQ, Cannon L, Wills MC, Luong-Tran C, Werner MA, Alexander KC, Strang J, Bal E, et al. (2013). Randomized controlled effectiveness trial of executive function intervention for children on the autism spectrum. *Journal of Child Psychology and Psychiatry;* 55(4): 374–383.

[17] Gresham FM, Elliott SN. Social Skills Improvement System—Rating Scales. Minneapolis, MN: Pearson Assessments; 2008

[18] Harrison P, Oakland T. Adaptive Behavior Assessment System Manual. 2nd ed. San Antonio, TX: Harcourt Assessment; 2003.

[19] Mullen EM. *Mullen Scales of Early Learning*. Circle Pines, MN: American Guidance Services; 1995

[20] Nahmias AS, Kase C, Mandell DS. Comparing cognitive outcomes among children with autism spectrumc disorders receiving community-based early intervention in one of three placements. *Autism.* 2014; 18(3): 311-320.

[21] Hayes AF, Preacher KJ. Statistical mediation analysis with a multicategorical independent variable. *British Journal of Mathematical and Statistical Psychology*. 2013; Epub ahead of print. DOI:10.1111/bmsp.12028.