2020 Gatlinburg Conference Symposium Submission

EXAMPLE

Symposium Title: Executive function in brain and everyday life: Lessons from autism, Down syndrome, and mixed etiology developmental disorders

Chairs: Nancy Raitano Lee[1], Benjamin Yerys[2,3]

Discussant: Lauren Kenworthy[4]

Overview: Executive functions, higher-level cognitive control skills thought to be important for the completion of complex tasks (Miyake et al., 2000), represent areas of weakness for individuals with neurodevelopmental disorders (Craig et al., 2018; Lee et al., 2016). Over the past several years, a body of research has amassed that ties executive function skills to important real-world outcomes, including adaptive function, academic achievement, and psychiatric functioning in the general population (Moriguichi et al. 2016). Similarly, researchers have begun to identify the neural correlates of executive function in typical development using various imaging techniques (Perone et al., 2018). Despite this, less is known about the behavioral and neural correlates of executive functioning in individuals with neurodevelopmental disorders. While preliminary research has documented relations between executive and adaptive function (Bertollo & Yerys, 2019; Kenny et al., 2019) and executive function and neural function (Voorhees et al., 2018) in groups with different neurodevelopmental disorders, there is still much to be discovered. Thus, the proposed symposium examines (1) neural and real-world correlates of executive function in several groups of young people who have neurodevelopmental disorder diagnoses, and (2) how executive function skills may, in fact, play a particularly important role in valid collection of neural data in these groups.

References/Citations:

- Bertollo, J. R., & Yerys, B. E. (2019). More Than IQ: Executive Function Explains Adaptive Behavior Above and Beyond Nonverbal IQ in Youth With Autism and Lower IQ. American journal on intellectual and developmental disabilities, 124(3), 191-205.
- Craig, F., Margari, F., Legrottaglie, A. R., Palumbi, R., De Giambattista, C., & Margari, L. (2016). A review of executive function deficits in autism spectrum disorder and attention-deficit/hyperactivity disorder. *Neuropsychiatric disease and treatment, 12,* 1191.
- Kenny, L., Cribb, S. J., & Pellicano, E. (2019). Childhood executive function predicts later autistic features and adaptive behavior in young autistic people: A 12-year prospective study. Journal of abnormal child psychology, 47(6), 1089-1099.
- Lee, N. R., Maiman, M., & Godfrey, M. (2016). What can neuropsychology teach us about intellectual disability?: searching for commonalities in the memory and executive function profiles associated with Down, Williams, and fragile X syndromes. *International Review of Research in Developmental Disabilities, 51*, 1-40.
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive psychology*, *41*(1), 49-100.
- Moriguchi, Y., Chevalier, N., & Zelazo, P. D. (2016). Development of executive function during childhood. *Frontiers in psychology*, *7*, 6.
- Perone, S., Almy, B., & Zelazo, P. D. (2018). Toward an understanding of the neural basis of executive function development. In *The neurobiology of brain and behavioral development* (pp. 291-314). Academic Press.
- Voorhies, W., Dajani, D. R., Vij, S. G., Shankar, S., Turan, T. O., & Uddin, L. Q. (2018). Aberrant functional connectivity of inhibitory control networks in children with autism spectrum disorder. *Autism Research*, *11*(11), 1468-1478.

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Paper 1 of 4

Paper Title: The IQ-Adaptive Functioning Gap in ASD: Associations with Behavior and Brain

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Introduction: Adaptive functioning, or the (social, communication, and daily living) skills critical to living independently, is consistently impaired in autism spectrum disorder (ASD). Moreover, among individuals with ASD without intellectual disability, there is a marked gap between IQ scores and adaptive functioning. Therefore, the cognitive skills captured by IQ do not serve to buttress adaptive skills among those without an intellectual disability. Indeed, there is increasing evidence that this gap between adaptive functioning and intellectual potential is associated with markers of poor outcome, including greater autistic traits/symptomatology and elevated ratings of co-occurring psychopathology, such as depression and anxiety symptoms (e.g., Kenworthy et al., 2010; Kraper et al., 2017). Nevertheless, whether this IQ-adaptive functioning gap is associated with other key skill areas or neurobiological indices in ASD has yet to be examined. Therefore, the primary aim of the current study is to assess the relationship between discrepancy scores in Differential Ability Scales (DAS-2) IQ score and Vineland Adaptive Behavior Scale (VABS-II) score, and both real-world executive functioning parent ratings using the Behavior Rating Inventory of Executive Function (BRIEF) and cortical thickness from magnetic resonance imaging (MRI) scans in both ASD and typically developing (TD) youth.

Methods: Two samples of sex-balanced ASD and TD youth (aged 8-17 years) were examined. Participants with behavioral data and FSIQ>70 included 177 ASD (mean age: 12.5 $\pm$ 2.9; 102 males) and 178 TD (mean age: 13.0 $\pm$ 2.9; 91 males) youth. A subsample of these participants, who met both behavioral and MRI inclusion criteria, included 88 ASD (mean age: 12.9 $\pm$ 2.8; 45 males) and 84 TD (mean age: 13.4 $\pm$ 2.8; 45 males) participants. ASD diagnoses were confirmed by expert clinicians using both the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2) and the Autism Diagnostic Interview-Revised (ADI-R). Parents of participants completed an interview (VABS-II) and questionnaire (BRIEF) about their children's behavior, and youth completed an IQ assessment (DAS-II) and an MRI scan as part of a larger study of brain and behavior in ASD. FreeSurfer software was used to quantify cortical thickness at ~150,000 vertices per hemisphere for the provided T-1 weighted MRI scans. Due to multiple comparison concerns, *a priori* regions of interest (ROIs) were identified from an existing meta-analysis of brain regions associated with "intelligence" (Basten et al., 2015). These regions were matched to those provided in the Destrieux atlas from FreeSurfer. Independent samples t-tests were used to examine group differences in FSIQ (estimated from the DAS-2 General Conceptual Ability Standard Score) and age. In both samples, TD youth had significantly higher FSIQ (p<.05); age did not differ between groups. Paired-samples t-tests probed differences between adaptive functioning and IQ within each group. The IQ-adaptive functioning discrepancy score was calculated for the VABS adaptive behavior composite score. The association between age and discrepancy scores was examined within each group using Spearman's rho, as age is non-normally distributed in both groups. Partial correlations were used to examine the association between IQ-adaptive discrepancy scores and BRIEF scores

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(Spearman's *rho*), and associations between IQ-adaptive functioning discrepancy and both cortical thickness values and the structural covariance of thickness across the eight ROIs (Pearson's *r*).

Results: ASD and TD youth show a significant discrepancy between adaptive functioning and IQ (ASD: t=19.2, p<.001; TD: t=9.6, p<.001). Because age is positively associated with this discrepancy score in both groups (ASD: r_s=.21, p<.01; TD: r_s=.25, p<.001), age was entered as a covariate in subsequent analyses. An ANCOVA reveals ASD youth show a greater discrepancy between IQ and the VABS composite score (F=46.4, p<.001). In ASD (but not TD) youth, the VABS-IQ discrepancy score was positively correlated with parent-rated executive function problems on the metacognition index (MCI) (r_s=.19 p<.05) but not the behavioral regulation index (BRI) of the BRIEF. In the MRI subsample, associations between the IQ-VABS discrepancy score and cortical thickness (in left inferior parietal lobe [r=-.22, p<.05] and right middle temporal gyrus [r=.24, p<.05]) was found only in the TD group. However, structural covariance between frontal and parietal regions (e.g., left superior parietal-inferior frontal) was associated with the IQ-VABS discrepancy only in the ASD group (r= -.28, p<01).

Discussion: To our knowledge, this is the first study to examine adaptive functioning-IQ score discrepancies in ASD: 1) in comparison to a TD control group, 2) in relation to executive functioning, and 3) in relation to a neurobiological index, cortical thickness in this instance. Here, we replicate prior findings of a relatively large IQ-adaptive behavior score discrepancy in children and adolescents with ASD (e.g., Pugliese et al., 2015) and extend prior findings by demonstrating that this discrepancy is greater in ASD relative to TD youth. For the first time we link this discrepancy with executive functioning problems, particularly metacognitive (e.g., working memory and planning) challenges. Given that much of the sample is composed of adolescents or emerging adolescents, this finding is aligned with prior research demonstrating maintenance of metacognitive problems in ASD alongside relative dissipation of behavioral regulation challenges during adolescence and into adulthood (Rosenthal et al., 2013; Wallace et al., 2016). Finally, we find associations between IQ-adaptive behavior discrepancy scores and brain structural metrics in key regions thought to underpin IQ/"intelligence" (Basten et al., 2015; Jung & Haier, 2007). Perhaps most interestingly, we find negative associations between IQ-adaptive skills discrepancy scores and frontal-parietal structural covariance in ASD youth unlike in TD youth. It's unclear from these data if brain drives behavior or vice versa, but these diverging patterns suggest possible dissociations in the neural architecture corresponding to ASD versus TD IQ-adaptive functioning behavioral profiles.

References/Citations:

- Basten, U., Hilger, K., & Fiebach, C. J. (2015). Where smart brains are different: A quantitative meta-analysis of functional and structural brain imaging studies on intelligence. *Intelligence*, *51*, 10–27. https://doi.org/10.1016/J.INTELL.2015.04.009
- Jung, R. E., & Haier, R. J. (2007). The Parieto-Frontal Integration Theory (P-FIT) of intelligence: Converging neuroimaging evidence. *Behavioral and Brain Sciences*. Cambridge University Press. https://doi.org/10.1017/S0140525X07001185
- Kenworthy, L., Case, L., Harms, M. B., Martin, A., & Wallace, G. L. (2010). Adaptive behavior ratings correlate with symptomatology and IQ among individuals with high-functioning autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *40*(4), 416–423. https://doi.org/10.1007/s10803-009-0911-4
- Kraper, C. K., Kenworthy, L., Popal, H., Martin, A., & Wallace, G. L. (2017). The Gap Between Adaptive Behavior and Intelligence in Autism Persists into Young Adulthood and is Linked to Psychiatric Co-morbidities. *Journal of Autism and Developmental Disorders*, *47*(10), 3007–3017. https://doi.org/10.1007/s10803-017-3213-2
- Pugliese, C. E., Anthony, L., Strang, J. F., Dudley, K., Wallace, G. L., & Kenworthy, L. (2015). Increasing Adaptive Behavior Skill Deficits From Childhood to Adolescence in Autism Spectrum Disorder: Role of Executive Function. *Journal of Autism and Developmental Disorders*, *45*(6), 1579–1587. https://doi.org/10.1007/s10803-014-2309-1
- Rosenthal, M., Wallace, G. L., Lawson, R., Wills, M. C., Dixon, E., Yerys, B. E., & Kenworthy, L. (2013). Impairments in real-world executive function increase from childhood to adolescence in autism spectrum disorders. *Neuropsychology*, *27*(1), 13–18. https://doi.org/10.1037/a0031299

- Wallace, G. L., Kenworthy, L., Pugliese, C. E., Popal, H. S., White, E. I., Brodsky, E., & Martin, A. (2016). Real-World Executive Functions in Adults with Autism Spectrum Disorder: Profiles of Impairment and Associations with Adaptive Functioning and Co-morbid Anxiety and Depression. *Journal of Autism and Developmental Disorders*, *46*(3), 1071–1083. https://doi.org/10.1007/s10803-015-2655-7

Paper 2 of 4

Paper Title: Real world executive functioning in childhood autism: Across settings and the cognitive spectrum

Authors: Benjamin Yerys[2,3] and Jessica Tschida[2,12]

Introduction: Executive function describes a set of abilities that allow people to control their thoughts, emotions, and actions in the service of achieving volitional goals. Executive function is impaired in many children and adolescents with a diagnosis of autism spectrum disorder (ASD). However, measuring executive function in the real world in children on the autism spectrum has been limited to the home setting and to children without a co-occurring intellectual disability diagnosis (ID). This study addresses these gaps by getting home and school ratings of executive function in children with ASD with and without ID.

Methods: Participants included 233 children who have an ASD diagnosis. Children were assigned to the ASD+ID group if they had an IQ score $\leq$ 75 (group n = 51; mean age = 10 years, 4 months, range 6 – 18 years), and the ASD-ID if they had an IQ >75 (n = 182, mean age = 10 years, 2 months, range 6 – 17 years). Ratings on the Behavior Rating Inventory of Executive Function (BRIEF) were obtained from home and the school setting. The BRIEF has 8 subscales of interest: Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, and Task Monitor. Caregivers were instructed to have the "individual who knows the child best at home and school" complete the BRIEF. Within each group, we compared age- and sex-normed T-scores for each School BRIEF subscale against the mean (T=50) with one-way t-tests. Using ANOVAs, we compared the BRIEF scales within each setting to determine if there was a peak impairment in the Shift scale, which has been demonstrated repeatedly in ASD-ID groups from the home setting (Gioia et al., 2002; Rosenthal et al., 2013). We also examined correlations for convergence between Home and School BRIEF ratings.

Results: Both clinical groups showed significant elevations compared to the population mean in the home and school settings. The ASD+ID sample shows significant elevations to the population mean (T=50); however, inspection of individual scales suggests only Shift (Home and School), Emotional Control (School), Initiate (School), Working Memory (Home and School), and Monitor (School) have mean T-scores in the elevated range. This differs from the ASD-ID group which has Shift (Home and School), Working Memory (Home), and Monitor (Home) as the only scales with mean T-scores in the elevated range. The ASD+ID group did not demonstrate a peak elevation in any single scale across either setting. The ASD-ID group demonstrated a peak elevation in the Shift scale in both settings (overall ANOVA F's>25, $p < 2 \times 10^{-16}$; individual scales $p<0.05$ after Bonferroni correction). For the ASD+ID group, correlation analyses revealed significant correlations between setting ratings on Inhibit (r=0.42), Emotional Control (r=0.34) and Organization of Materials (r=0.44). For the ASD-ID group, correlation analyses revealed significant correlations between setting ratings on Inhibit (r=0.38), Shift (r=0.23), Emotional Control (r=0.30), Working Memory (r=0.27), Plan/Organize (r=0.31), Organization of Materials (r=0.37), and Monitor (r=0.38).

Discussion: To our knowledge, this is the first study to directly report on real world executive function in the home and school settings for an ASD+ID sample, and the first to report on ASD-ID in the school setting. The ASD-ID group replicated prior findings by showing a peak elevation in Shift in the Home setting, and the present study is the first to show this peak elevation exists in the School setting as well. The ASD+ID group did not exhibit a peak elevation in Shift or any other scale. Correlation analyses reveal moderate convergence in parent ratings for the ASD-ID group, but much less agreement in the ASD+ID group. The lower convergence in the ASD-ID group may result from a number of reasons, such as variability in environmental demands or

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performance opportunities across the Home and School setting, and wording of items not being ideal for those with limited expressive language skills. Taken together, these findings extend the robust findings in the ASD-ID population, but highlight opportunities for optimizing identification of executive function weaknesses the ASD+ID population. This has significant treatment implications, because if we can reliably index executive function weaknesses in the ASD+ID population across settings, then we can target these weaknesses in treatment to better meet the needs of this segment of the ASD population.

References/Citations:

- Gioia, G. A., Isquith, P. K., Kenworthy, L., & Barton, R. M. (2002). Profiles of everyday executive function in acquired and developmental disorders. *Child Neuropsychology*, *8*(2), 121–137.
- Rosenthal, M., Wallace, G. L., Lawson, R., Wills, M. C., Dixon, E., Yerys, B. E., & Kenworthy, L. (2013). Impairments in real-world executive function increase from childhood to adolescence in autism spectrum disorders. *Neuropsychology*, *27*(1), 13–18.

Paper 3 of 4

Paper Title: Neural and behavioral correlates of working memory in Down syndrome

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Introduction: Down syndrome (DS), the most common genetic cause of intellectual disability, is characterized by impairments in executive function that exceed global learning challenges, with prominent deficits in working memory (Lee et al., 2016). Despite numerous studies documenting working memory impairments in this group, we know little about the behavioral and neural correlates of this aspect of executive function in individuals with DS. Thus, the proposed research sought to fill this gap in the literature by examining relations between working memory skills and both adaptive behavior and brain morphometry in a sample of youth with DS.

Methods: Twenty-four children and young adults with DS participated in the current study (M age= 16 $\pm$ 5 years; 58% female; M IQ=52 $\pm$ 12). These participants were part of a larger study of brain and cognitive development in DS conducted at the National Institute of Mental Health Intramural Research Program.

Data acquisition: Structural neuroimaging was completed (without sedation) on a 3-Tesla General Electric magnetic resonance imaging scanner. High-resolution T1-weighted images were acquired. Structural brain volume was parcellated with the Freesurfer Image Analysis Suite. The Desikan-Killiany atlas (Desikan et al., 2006) was used to further parcellate the cortex.

In addition to neuroimaging, participants completed tests of cognitive function, including the Differential Abilities Scales - Second Edition Recall of Digits - Forward and Backward subtests. A composite score (DAS-2 working memory composite) from these two tasks was utilized for the current research. Parents completed the Adaptive Behavior Assessment System - Second Edition (ABAS-II). The three composite scores – Conceptual, Social, and Practical – were examined in the current research.

Identifying neural regions of interest: Based on (a) our lab's prior work (Lee et al., under review) in which prominent frontal-cerebellar abnormalities were noted for youth with DS relative to typically developing controls and (b) research implicating regions of the frontal lobes and cerebellum in the completion of working memory tasks (Marvel & Desmond, 2016; Eriksson et al., 2015), the current research focused only on these regions. In Lee et al. (under review), only one Desikan-Killiany frontal subregion significantly differed between participants with DS and controls after correcting for multiple comparisons — the

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superior frontal gyrus. Similarly, cerebellar gray matter volume differed significantly from controls (after correcting for multiple comparisons). Thus, these two regions were the focus of the current study's investigation of working memory - brain morphometry relations.

Analytic approach: Prior to completing primary analyses, age was regressed out of raw scores on the DAS-2 and ABAS-II and standardized residuals were saved for subsequent analyses. To examine relations between working memory as measured by the DAS-2 and adaptive function as measured by the ABAS-II, Pearson correlations were completed. To examine relations between the DAS-2 working memory composite and both superior frontal and cerebellar gray matter volumes, hierarchical linear regression was used with age and sex entered into the first step (given research documenting sex and age effects on brain morphometry; Lenroot et al., 2007) and the DAS-2 Digits composite score entered into step 2.

Results: First, significant correlations were identified between the DAS-2 working memory composite and two of three adaptive behavior composites – Conceptual ($r=.62$, $p<.01$) and Practical ($r=.57$, $p<.01$). When relations between the DAS-2 Digits composite and brain were evaluated, significant relations were also found. Specifically, when the DAS-2 working memory composite was entered into the regression model predicting superior frontal gyrus volume, it added an additional 9% of variance (F change $[1,20] = 4.5$, $p<.05$) over and above the effects of age and sex. When predicting cerebellar gray matter volume, the DAS-2 working memory composite added 31% additional variance (F change $[1,20] = 14.0$, $p<.01$) above and beyond the effects of age and sex.

Discussion: The results of the current investigation provide support for significant relations between lab-based working memory performance and adaptive function, complementing prior research examining relations between executive and adaptive function using parent-report measures in children with DS (Daunhauer et al., 2017). Moreover, they document relations between individual differences in working memory and brain structure. As frontal and cerebellar abnormalities are prominent features of the DS neuroanatomic phenotype, these results provide further support for the need for future research on the developmental trajectories and genetic/epigenetic underpinnings of these brain regions in individuals with DS.

References/Citations:

- Daunhauer, L. A., Gerlach-McDonald, B., Will, E., & Fidler, D. J. (2017). Performance and ratings based measures of executive function in school-aged children with Down syndrome. *Developmental neuropsychology, 42*, 351-368.
- Desikan, R. S., Segonne, F., Fischl, B., Quinn, B. T., Dickerson, B. C., Blacker, D., . . . Killiany, R. J. (2006). An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest. *Neuroimage, 31*, 968-980.
- Eriksson, J., Vogel, E. K., Lansner, A., Bergström, F., & Nyberg, L. (2015). Neurocognitive architecture of working memory. *Neuron, 88*, 33-46.
- Lee, N. R., Maiman, M., & Godfrey, M. (2016). What can neuropsychology teach us about intellectual disability?: searching for commonalities in the memory and executive function profiles associated with Down, Williams, and fragile X syndromes. *International Review of Research in Developmental Disabilities, 51*, 1-40.
- Lee, N.R./Nayak , A., Irfanoglu , M., Sadeghi , N., Stoodley , C. Adeyemi , E., Clasen , L., & Pierpaoli, C. (under review). Hypoplasia of cerebellar afferent networks in Down syndrome revealed by diffusion MRI tensor based morphometry.
- Lenroot, R. K., Gogtay, N., Greenstein, D. K., Wells, E. M., Wallace, G. L., Clasen, L. S., ... & Thompson, P. M. (2007). Sexual dimorphism of brain developmental trajectories during childhood and adolescence. *Neuroimage, 36*, 1065-1073.
- Marvel, C. L., & Desmond, J. E. (2016). The cerebellum and verbal working memory. In *The Linguistic Cerebellum* (pp. 51-62). Academic Press.

Paper Title: Who can do neuroimaging research? Examining psychological factors that predict scan success in children who have neurodevelopmental disorders

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Introduction: Advances in clinical and behavioral protocols to support successful neuroimaging scan experiences for neurodevelopmental disability groups have expanded their participation in neuroimaging studies (Gabrielsen et al., 2018; Nordahl et al., 2016; Kuschner et al., 2019). Children with neurodevelopment disorders who are minimally verbal or nonverbal (and often also have intellectual disability) were previously excluded from neuroimaging studies due to assumptions of difficulties with remaining still, tolerating novel sensory experiences, inhibiting repetitive behaviors, and understanding/following directions associated with the scan process. New clinical and behavioral protocols show scan success rates from 75-100%. This means neuroimaging studies of brain structure and function have the potential to be more inclusive and offer more promise for scientific and treatment progress, particularly in areas so regularly compromised in neurodevelopmental disorders, such as executive functioning. To further optimize clinical and behavioral protocols in order to understand neural correlates of crucial areas of functioning, we can now consider child characteristics – such as temperament – in order to preview neuroimaging support needs and, ultimately, determine likelihood of scan success in order to maximize comfort and mitigate stress during study participation.

Methods: Participants included 42 children with neurodevelopmental disorders or genetic syndromes ages 8 to 12 years (mean age=10.3 years, SD=1.4; Nonverbal IQ mean=54.5, SD=15.8). With the support of the *MEG Protocol for Low-Language/Cognitive Ability Neuroimaging* (MEG-PLAN; Kuschner et al., 2019), all participants completed MEG protocols using a 275-channel CTF MEG system. Paradigms were short (five to fifteen minutes) and were passive and thus did not require task performance. We report on a pure tone paradigm. 150 trials each of interleaved 500Hz and 1000Hz tones were presented at a pseudo-randomized interstimulus interval (ISI) in the range of 1500 to 2000 ms. Parents completed the developmentally appropriate version of the Carey Temperament Scales (Carey & McDevitt, 1995) for their child to report on behavioral style across nine categories of temperament. Questionnaire version was chosen based on nonverbal mental age, with 35 parents completing the Behavioral Style Questionnaire (for 3 to 7 years) and 7 parents completing the Toddler Temperament Scale (for 1 to 35 months). We created groups of "Successfully" and "Unsuccessfully" scanned participants; success was operationalized as reaching a point in the MEG scan where data was *acquirable* (i.e., the MEG machine was turned on and a paradigm was actively administered). Dependent variables included temperament category scores from the from the Carey Temperament Scale, including Activity level, Adaptability, Approach to novelty, Distractibility, Emotional intensity, Persistence, Quality of mood, Rhythmicity, and Sensory sensitivity. We compared temperament ratings with independent samples t-tests. Note, data collection for this study is ongoing; the final, larger sample may allow for further analyses comparing diagnostic groups.

Results: Using MEG-PLAN a 76% success rate for obtaining evaluable MEG data was achieved. Temperament scores were then examined between the children who scanned "successfully" (n=32) versus those with "unsuccessful" scans (n=10). Results suggest that children with unsuccessful scans were more likely to have external stimuli alter their ongoing behavior (p=.03, d=.8), show greater energy level in response to their environment (p=.03, d=.7), and be rated by their parent as more globally difficult to manage (p=.03, d=.7). There were no differences across the remaining temperament scales based on who did or did not scan successfully.

Discussion: Results suggest that temperament features related to distractibility, intensity of emotional responses, and general manageability are associated with difficulty completing neuroimaging research protocols. Ironically, these features could be considered proxies for behaviors under the umbrella of executive functions and behavioral dysregulation. Indeed, as the field

aims to expand who can participate in neuroimaging research in order to answer questions about neural correlates of executive functioning, it may be these executive weaknesses that limit successful neuroimaging scanning. Results also indicate that children who show these temperament profiles may require extra, tailored supports with an eye toward behavioral regulation. Neuroimaging research is costly in terms of both participant time and stress, and institutional resources. Thus, to make the greatest use of these precious resources it is imperative to continue refining and optimizing protocols so that all individuals who wish to participate are capable of contributing to our knowledge of brain function and development.

References/Citations:

- Carey, WB., McDevitt, SC. The carey temperament scales. Scottsdale, AZ: Behavioral-Developmental Initiatives; 1995.
- Gabrielsen TP, Anderson JS, Stephenson KG, Beck J, King JB, Kellems R, et al. Functional MRI connectivity of children with autism and low verbal and cognitive performance. Molecular Autism; 2018;9:1–14.
- Kuschner, E.S., Kim, M., Dipiero, M., Ku, M., Bloy, L., Edgar, C.J., Roberts, T.P.: "A clinical and behavioral protocol for obtaining electrophysiological data with children with low language and cognitive ability" at the Annual Meeting for the International Society for Autism Research in Montreal, Canada, May 2019.
- Nordahl CW, Mello M, Shen AM, Shen MD, Vismara LA, Li D, et al. Methods for acquiring MRI data in children with autism spectrum disorder and intellectual impairment without the use of sedation. J Neurodev Disord. 2nd ed. BioMed Central; 2016;8:20.