AN EXAMINATION OF FACTORS IMPACTING EXECUTIVE FUNCTIONING IN CHILDREN WITH DEVELOPMENTAL DELAYS

by

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A DISSERTATION

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DISSERTATION ABSTRACT

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Title: An Examination of Factors Impacting Executive Functioning in Children with Developmental Delays

Executive functioning abilities have been associated with important behaviors such as adaptive skills and cognitive abilities in children with and without disabilities. Executive functioning has primarily been measured as a strong predictor of later abilities in children with neurodevelopmental disabilities, such as attention-deficit/ hyperactivity disorder. However, little to no research exists on the role of executive functioning in the lives of children with developmental delays. Developmental delay refers to a broad descriptive category that encompasses a heterogeneous group of children who do and do not yet meet diagnostic criteria for a disability but experience delays in at least one developmental domain. This population presents with a wide range of ability levels and life outcomes. Children with developmental delays represent a common, but understudied, population.

The current study explored the relation between child variables in preschool with executive functioning in middle childhood as assessed by direct and indirect (caregiver-reported) measures. Ninety-three children who were identified as having a developmental delay in preschool participated in this study. Seventy-nine of the children continued to meet criteria for a developmental delay or disability in middle childhood. Children

completed direct measures of overall cognition, autism symptomology, and executive functioning while caregivers reported on their child's adaptive behavior and executive functioning through an interview and behavior checklist. Child diagnostic classification and adaptive behavior in preschool did not predict later executive functioning, whether reported by parents or directly measured. The addition of variables measuring autism symptomology and overall cognition in middle childhood did not further explain the relation between child characteristics in preschool and executive functioning in middle childhood. However, caregiver-reported adaptive behavior in middle childhood accounted for a significant amount of the variance in caregiver-reported executive functioning. Future research should continue to examine the characteristics of children with developmental delays across different developmental stages. Additional examinations of the directionality of executive functioning and other key child behaviors, such as adaptive skills, are recommended.

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TABLE OF CONTENTS

LIST OF FIGURES

Figure Page

LIST OF TABLES

Table Page

CHAPTER I

INTRODUCTION

Executive functioning (EF) is a broad cognitive construct related to higher-order thinking processes implicated in daily living. Purposeful higher-order domains associated with EF typically include working memory (i.e., ability to retain and manipulate information over short periods of time), cognitive flexibility (i.e., ability to sustain and shift attention, application of different rules), and inhibition (i.e., ability to set priorities and control actions or responses; Diamond, 2013; Zelazo & Muller, 2002). EF skills begin to develop in childhood and mature through early adulthood. They are considered malleable and can be impacted by life events as well as intervention.

The development and role of EF is of interest to researchers and practitioners. As a construct, EF refers to the intertwined cognitive processes implicated in planning and control in daily life. During childhood, EF has been associated with increased academic achievement (e.g., Hooper et al., 2002; Masten et al., 2012) and emotional regulation (e.g., Blair et al., 2005). As an adult, EF is relevant to variables such as job success (e.g., Bailey, 2007), marital harmony (e.g., Eakin et al., 2004), physical health (e.g., Crescioni et al., 2011; Davis et al., 2011) as well as the presence of mental health disorders such as addiction (e.g., Baler & Volkow, 2006).

Measurement of Executive Functioning

Research on EF has applied a mixture of procedures including direct (e.g., neurophysiological measures) and indirect (i.e., behavior rating scales) measures (Craig et al., 2016). Direct assessment of EF has dominated the neuropsychological literature associated investigating EF. Depending on the area of investigation, assessment batteries

may contain tasks across multiple areas of EF or specific to one or two different EF constructs. Direct measures of EF provide a discrete, standardized look into specific cognitive processes. However, direct measures of EF have been criticized for their narrow measurement and lack of generalization to everyday functioning.

Caregiver- or informant-reported measures of EF have gained popularity in recent years. Indirect measures of EF focus on the application of EF skills to daily living skills. The use of applied, informant measures of EF (e.g., Behavior Rating Inventory of Executive Function [BRIEF]; Gioia et al., 2015) has been associated with higher ecological validity in comparison to neuropsychological tests alone. In a meta-analysis of EF in ASD, studies including self- or caregiver- reported ratings had larger effect sizes (0.64 to 5.60) when compared with studies only utilizing experimental tasks (Demetriou et al., 2018, p. 1201). Future research should use both direct measures and indirect, or applied, measures of EF with child populations and with people with neurodevelopmental disabilities (Demetriou et al., 2018; Semrud-Clikeman et al., 2010). Comprehensive evaluations of EF may be more appropriate, and representative, when investigating cognitive processes in individuals with developmental disabilities or delays.

Executive Functioning in Neurodevelopmental Disorders

Deficits in EF are commonly observed in individuals with neurodevelopmental disabilities, in particular individuals with autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD). Cognitive profiles associated with ASD and ADHD have been studied at length; however, many questions remain regarding the underlying neural mechanisms and implications for specific cognitive differences in individuals with neurodevelopmental disabilities. The co-occurrence of EF deficits in

neurodevelopmental disabilities is expected and reflects an additive commodity rather than a separate, specific condition. That is, specific differences in EF are present across neurodevelopmental conditions. However, the presence of deficits in EF by disability group varies based on the individual and disability. Only when impairments the in EF are present above and beyond what is consistent and expected for symptoms of a specific disorder, are additional diagnoses (e.g., ADHD) considered.

Autism Spectrum Disorder. The diagnostic characteristics associated with ASD have been linked to specific weaknesses in EF (e.g., Kenworthy et al., 2009). Impairments in EF have been tied to both restrictive and repetitive behaviors (RRBs) as well as social communication difficulties (e.g., Boyd et al., 2009; Leung et al., 2016; Torske et al., 2018). Core symptoms of ASD, such as deficits in social communication and interactions, have been associated with weaknesses in task initiation, working memory, cognitive flexibility, as well as adaptive behavior on direct and caregiver-reported measures (Blijd-Hoogewys et al., 2014; Gilotty et al., 2002). Behaviors related to social reciprocity and awareness have been theorized as the basis for EF deceits. An emerging body of research is focusing on the impact of ASD symptoms and symptom severity on differences in EF for children and adults.

Children with ASD often have deficits in EF when compared to their same-age peers, specifically in areas of caregiver-reported flexibility and planning/organization (e.g., Blijd-Hoogewys et al., 2014; Semrud-Clikeman et al., 2010). Mixed results have been reported for the prevalence of deficits in task initiation (e.g., Bramham et al., 2009) and working memory (e.g. Geurts et al., 2004) as well as response inhibition (e.g., Ozonoff & Jensen, 1999; Ozonoff & McEvoy, 1994; Ozonoff & Strayer, 1997) when

compared to typically developing (TD) peers. Despite reported differences in areas of EF deficits in individuals with ASD, it is believed that people with ASD present with an overall EF profile different from other neurodevelopmental disorders.

Previously published meta-analyses and systematic reviews of EF in ASD have focused on one or two specific subdomains of EF. While past research has been dedicated to identifying qualitative features of EF in children with ASD, a growing line of research has focused on the impact of EF on the daily lives of people with ASD. Research examining the impact of EF symptoms on adaptive behaviors in children with ASD has shown an overwhelming impact of caregiver-report EF on adaptive skills such as communication, self-care, and independence (e.g., Geurts et al., 2004; Kenny et al., 2019). In a study of adolescents with ASD, Pugliese et al. (2016) reported caregiver-reported EF predicted adaptive behavior and was negatively correlated with overall adaptive behavior. This finding was replicated in a sample of children with comorbid ASD and ADHD, with EF again predicting adaptive behavior after accounting for child age and cognitive abilities (Kenny et al., 2019). Pervasive deficits in cognitive flexibility as well as skills such as initiation, self-monitoring, communication, and self-care skills have been reported in children and adolescents with ASD (Demetriou et al., 2018; Kenny et al., 2019; Yerys et al., 2019). Investigations regarding an overall framework for the presentation of EF in ASD continue with a focus on identifying the impact of EF on adaptive skills in children with ASD.

Attention Deficit/Hyperactivity Disorder. A wealth of research exists on EF in children with ASD. Other work has focused on a different disability: ADHD. ADHD is a neurodevelopmental disorder characterized by a pattern of inattention and/or

hyperactivity and impulsivity (APA, 2013). Similar to ASD, core behavioral characteristics specific to ADHD are implicated in EF, such as inhibition and working memory. Specific EF profiles associated with children with ADHD have emerged as definitively different from children with ASD (e.g., Semrud-Clikeman et al., 2010).

The level of EF deficits compared across diagnostic groups continues to be debated; however, core areas of deficit have been identified across groups. Earlier research reported children with ASD presented with more robust EF deficits when compared with children with ADHD and TD children (Geurts et al., 2004; Pennington & Ozonoff, 1996; Semrud-Clikeman et al., 2010). Other research has suggested less severe EF deficits in children with ASD when compared to children with ADHD (Happé et al., 2006). Consistent findings have included areas of deficits across groups. Not surprisingly, children with ADHD typically show greater inhibitory problems compared with children with ASD and TD (e.g., Geurts et al., 2004; Happé et al., 2006) while children with ASD show impairment in both flexibility and planning on caregiver-reported measures (e.g., Craig et al., 2016). Deficits in working memory have been implicated in both groups, with mixed results for with children with ADHD when compared to controls (e.g., Geurts et al., 2004; Semrud-Clikeman et al., 2010).

Similar to ASD, deficits and differences in children with ADHD have been reported in relation to EF and adaptive behavior. In a study comparing children with prenatal alcohol exposure to children with and without ADHD, Ware et al. (2012) examined the relationship between EF and adaptive behavior. For children with ADHD or with prenatal exposure to alcohol, adaptive behavior predicted direct measures of EF. However, the impact of EF on adaptive behavior were more broad for the ADHD group

and was observed across more EF domains in comparison to the pre-natal alcohol exposure group. Similar studies investigating adaptive behavior in children with ADHD have continued to identify consistent deficits, specifically in overall adaptive behavior as well as domains such as socialization and in self-cares skills (e.g., Balboni et al., 2017; Di Pinto, 2006).

Executive Functioning in Developmental Delays

Missing from the literature on EF in children with disabilities is children with developmental delays. In comparison to ASD or ADHD, developmental delay (DD) refers to a general categorization of delayed development across multiple domains (e.g., cognitive, fine and gross motor, social, language). Unlike a medical diagnosis of a neurodevelopmental disorder or disability, DD is a descriptive category broadly used in early intervention or community settings (e.g., eligibility for an Individualized Family Support Plan) as well as medical settings (Rosenburg et al., 2008). The descriptive categorization of DD is overarching and may encompass children diagnosed with disabilities (e.g., ADHD, ASD, intellectual disability) as well as children presenting with delays. The estimated prevalence of DD is around 1 in 6 children in America (Boyle et al., 2011; Rosenburg et al., 2008). Children with DD fall into a heterogeneous category that may or may not be indicative of future disability status. Information on the impact of DD is scarce, partially due to the wide-range of behavioral presentations within this category. The outcomes for children identified with DD in early childhood vary with up to 76% of children initially identified as having a DD going on to meet criteria for a disability in adolescence (Boyle et al., 2011). Children with DD represent a high-

incidence population with broad behavioral characteristics resulting in widespread impact on their families and communities.

An overwhelming amount of research is available on the presentation of EF in children with ASD and ADHD with comparative TD peer groups. To date, relatively little research has been done on the EF profiles of children with DD. Dawson and colleagues (2002) examined differences in EF performance between on direct, neuropsychological prefrontal tasks in preschool-age children with ASD and DD. Reported differences were confounding, with similar performance across groups in areas such as direct EF and adaptive behavior. Additional research on children with DD has focused primarily on clinical populations and has not included children with delays that are significant but not yet meeting diagnostic criteria for a specific disorder. Overall, research on EF in children with DD is severely limited.

As a group, children with DD present with a significant potential to benefit from early and targeted intervention services. The positive effects of early intervention with this population have been widely documented, with a focus on targeted as well as broad interventions (e.g., Hwang et al., 2013; Lin & Cherng, 2019; Rosenburg et al., 2008). Children with DD are particularly well-poised to benefit from interventions targeting vital adaptive and EF skills. By identifying child variables associated with positive outcomes in children with DD, practitioners and caregivers can continue to pursue interventions that may have wide-reaching and positive effects across a broad population.

Purpose of the Study

EF refers to important cognitive processes for daily living and overall functioning. EF is a wide-reaching and malleable construct with many broad implications for activities

of daily life. The impact of EF has been measured on important skills, such as adaptive behavior, in children with ASD and ADHD. Research on applied EF has emerged in the field of neurodevelopmental disabilities, with recent works examining the role of ASD and ADHD symptoms on EF.

However, little research exists linking adaptive skills and EF in children with DD. Importantly, adaptive behavior has not been connected to the development on EF in children with DD and later outcomes. Positive relationships between applied (caregiver-reported) EF and adaptive behavior had been reported in children with ASD and ADHD. Exhaustive research has been conducted with other sample groups though children with DD continue to represent a previously under-investigated population.

The purpose of the present study was to extend the current research on the understanding of EF in children with DD. This exploratory study looked at the impact of two important factors on EF in children identified with DD: adaptive behavior and diagnosis. See Figure 1 for a conceptual model detailing relations between variables of interest for this study. This study included a sample of children with DD assessed in preschool and in middle childhood. First, the predictive power of preschool adaptive functioning and diagnostic classification (i.e., with or without community diagnosis of ASD) on current EF was investigated. The variable of adaptive behavior was identified based on research showing a positive impact between adaptive behavior and applied EF in children with ASD and ADHD (e.g., Ware et al., 2012). Diagnostic categorization was also selected based on the wealth of research on children with ASD. The sample in the current investigation included children with DD, including some with specific diagnoses such as ASD. Therefore, it was important to measure the impact of ASD disability status

on EF given the expected, wide range of ability levels in the sample. Lastly, the addition of child ASD symptom severity and overall cognitive abilities was investigated after accounting for previous adaptive behavior and diagnostic categorization. These variables have been associated with applied and direct EF in children with ASD (Kenny et al., 2019; Yerys et al., 2019) and have not yet been investigated in children with DD. Previous research examining the relation between EF and ASD symptoms has focused on the predicted powers of EF on ASD symptoms on traits (e.g., Boyd et al., 2009; Leung et al., 2016; Lopez et al., 2005; Torske et al., 2018). The present study investigated the predictive impact of ASD symptoms on EF.

Children with DD make up a sizeable percentage of the population but are often not the focus of research on EF. Research previously focused on applied and direct EF has focused on diagnostic categories such as ASD and ADHD; however, children with DD are largely missing from the literature. Therefore, further investigation into early characteristics impacting EF is necessary in order to inform future research and intervention planning for children with DD and their families. This study addressed a major gap in the research by investigating child variables that predict EF in a heterogeneous sample of children identified with DD. Two time points were included: Time 1 (preschool) and Time 2 (middle childhood).

Research Questions

This study aims to address the following research questions:

1. What are the relations between child characteristics and EF in children with DD?

Understanding child variables associated with EF is important for caregivers and practitioners given the impact of EF skills on children's daily life. EF has been

investigated as a predictive variable for outcome measures such as adaptive behavior and cognition (e.g., Balboni et al., 2017; Craig et al., 2016; Kenny et al., 2019). However, few studies examine variables that predict EF. This study included an assessment of preschool functioning in order to examine possible early predictors of direct and applied EF in middle childhood. Based on previous research, it was predicted that adaptive behavior and cognitive abilities would be positively related to both direct and applied EF. In addition, it was predicted that ASD symptoms severity would be negatively correlated with EF.

2. Do measures of adaptive functioning and community diagnosis in preschool predict unique variance in applied EF in middle childhood for children with DD?

Caregiver reports of applied EF have been reported to predict variables such as ASD symptom severity and adaptive behaviors (e.g., Kenny et al., 2019; Yerys et al., 2019) in children with neurodevelopmental disabilities. The current study investigates the predictive power of early (preschool) adaptive behavior and early diagnosis on caregiver reported EF in children with DD in middle childhood. Examining this relation is important when considering the focus of early intervention for children with DD and their families. Based on the wealth of literature linking deficits in EF to ASD and the emerging research on the role of adaptive behavior in EF, it was hypothesized adaptive functioning and community diagnosis in early childhood would significantly predict unique variance in applied EF.

3. Do measures of adaptive functioning and community diagnosis in preschool predict unique variance in direct measures of EF in middle childhood for children with DD?

Previous research including direct measures of EF has primarily been exploratory and has not focused on the predictive power of child variables. Direct measures of EF vary widely by construct and domain and have not been researched exhaustively with the DD population. Based on previous research examining a subsection of the DD population (i.e., ASD/ADHD) adaptive behavior and diagnosis in preschool was expected to predict child performance on direct measures of attention and inhibition. An a priori hypothesis was not included for direct measures of working memory due to the exploratory nature of the analysis and previous, inconclusive findings (e.g., Geurts et al., 2004).

4. Does cognition and ASD symptoms explain additional, unique variance in applied EF in middle childhood after controlling for adaptive functioning and community diagnosis for children with DD?

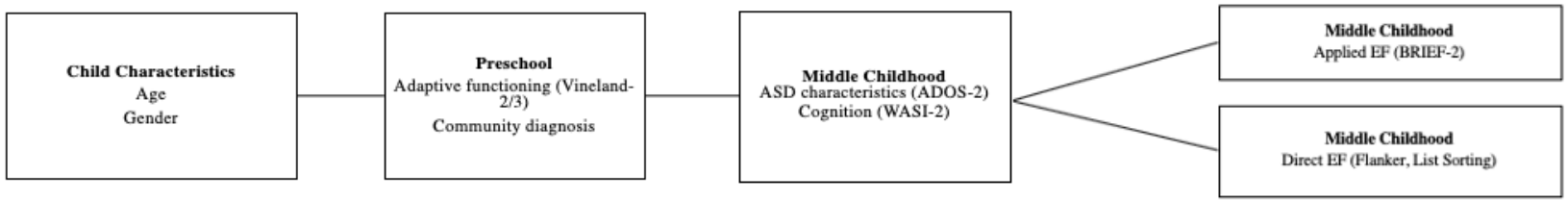
The impact of ASD symptom severity and cognition in relation to EF in children with ASD has been studied extensively; however, the relation between these variables is unknown in children with DD. By examining additional variables that may impact EF in middle childhood, this research question aimed to continue to investigate the effect of child variables in preschool on EF. Based on research in children with ASD, it was hypothesized that ASD symptoms and overall cognitive functioning (IQ) in middle childhood would explain additional, unique variance in applied EF in middle childhood after accounting for adaptive behavior and diagnostic status in preschool.

5. Do cognition and ASD symptoms explain additional, unique variance in direct EF in middle childhood after controlling for adaptive functioning and community diagnosis in preschool for children with DD?

Similar to applied EF, research has focused on ASD symptoms and cognitive abilities in related to direct measures of EF. Again, reports are significantly varied in the specific direction and EF construct with regards to ASD symptoms and cognition. It was hypothesized ASD symptoms and cognition in middle childhood would explain unique variance in the relationship between direct measures of attention and inhibition in middle childhood and community diagnosis with adaptive behavior in preschool. However, the same prediction was not expected for working memory based on previous, inconclusive results (e.g., Geurts et al., 2004).

Figure 1

Conceptual Model



CHAPTER II

METHODS

Participants

Participant data were sampled from the first wave of the Kid Brain Network (KBN; R21 MH114075, McIntyre & Sabb, MPIs), a study designed to examine the neural functional connectivity networks, behavior, and symptoms of children with DD in a sample of children with DD drawn from the Northwestern United States. The KBN study includes both clinical and neuroimaging data; clinical data were used for this study.

Previous Research Participation. Participants from KBN included caregivers and children who participated in previous longitudinal research investigating behavior and development in children with DD and ASD (i.e., Oregon Early Autism Project [OEAP], Fairway Foundation Small Grant, McIntyre, PI; Oregon Parent Project [OPP], R01 HD059838, McIntyre, PI). All OEAP and OPP participants were recruited from preschool and early invention agencies serving children with developmental delays and disabilities in a midsize city in Oregon. Children who were nonambulatory, deaf, or blind were not included in OEAP and/or OPP.

OEAP. Children were eligible for Wave 1 OEAP if they were preschool-aged (*M* = 4.5 years) and had a medical diagnosis and/or educational eligibility of ASD. Sixty children participated at the preschool Wave 1 time point and were primarily white (70.1%) and male (83.2%). Since Wave 1, two additional waves of OEAP data were collected. Subsequent waves of OEAP included caregivers who provided prior consent for re-contacting as well as additional children and caregivers contacted through local school districts.

OPP. Children were eligible for OPP if they were preschool-aged (*M* = 3.1 years) and had been identified as having a developmental delay or disability from an educational agency or community medical provider. Of the developmental diagnoses reported in the OPP sample, speech language delay (41.4%) and ASD (22.2%) were the most commonly at Wave 1. Participants from OPP include 180 preschool-aged children. Child participants from OPP were primarily white (91.6%) and male (75.5%).

Screening. All study procedures were approved by the Institutional Review Board at the University of Oregon. Recruitment for KBN included invitation letters sent from KBN research staff to families previously involved in OEAP and OPP. Interested families contacted the research office and were screened for eligibility. Families were considered eligible for the study if they were able to participate in at least one clinical visit. Families that did not consent to the neuroimaging visit were still invited to participate in the clinical visit. Verbal consents were obtained from potential caregiver participants before the start of eligibility screening and written informed consents were obtained during the initial clinical visit from families who were found eligible.

Study Procedures

All data were collected prior to analysis from a larger, ongoing study (i.e., Time 1; preschool = OEAP/OPP, Time 2; middle childhood = KBN Wave 1). Preschool data were drawn from two separate studies (OEAP and OPP) that had similar procedures involving parent interviews and surveys. In the present study, caregiver-reported diagnosis at preschool and caregiver-reported adaptive behavior were included. Data collection for middle childhood (KBN Wave 1) took place across three different data

collection points during the same wave: 1) mail-home packet, 2) clinical visit, and 3) neuroimaging visit. Prior to the clinical visit, caregivers completed a mail-home packet with measures of caregiver-reported EF as well as other measures not used in this investigation. The home-based caregiver measures took approximately 1 hour to complete.

Clinical visits were scheduled for a 2-hour time period that was convenient for the caregiver and child. All clinical assessments took place at a University-affiliated research clinic. Caregiver and child participants were evaluated during the clinical visit. All measures were administered by two research assistants (i.e., one for the child participant, one for the caregiver participant) from school psychology and special education doctoral programs. Clinical visits are comprised of three parts: consent, mock scanner visit, and clinical assessment (measures described below). The consent process included the research assistants reviewing the schedule for the visit, gaining verbal and written consent from the caregiver, and gaining verbal assent from the child. Next, in preparation for the neuroimaging visit, the research assistants accompanied the caregiver and child to an adjacent building for a mock scanning procedure at the neuroimaging center. The mock scanner visit took approximately 30 minutes, including walk time, and was conducted by a research assistant affiliated with the neuroimaging center. Following the mock scanner visit, child and caregiver participants were evaluated separately by research assistants. Direct clinical assessments took approximately 120 minutes. At the conclusion of the clinical visit, the caregiver was compensated $80 for their time.

The third data collection visit took place during the neuroimaging visit. The neuroimaging visit followed the clinical visit and was scheduled during the mock scanner

procedure. Child participants completed direct measures of EF (i.e., Flanker, List Sorting) prior to neuroimaging at a University-affiliated neuroimaging center. A trained research assistant administered all direct measures of EF. Direct measures of EF took approximately 15 minutes. Magnetic resonance imaging data were collected following direct measures of EF and are not reported for this study. Following the neuroimaging visit the caregiver was compensated $80 for their time.

Measures

Caregiver-Report Measures. Caregiver-report measures were included the mail-home packet and completed prior to the clinical visit or completed via interview during the clinical visit. The packet included measures of applied EF and as well as measures not used in this current investigation (e.g., child problem behavior, measures of sensory modulation). Additional information (i.e., demographic information) was collected from caregivers as a part of the clinical visit.

Adaptive behavior. Adaptive behavior was measured at preschool and middle childhood using the Vineland Adaptive Behavior Scales, Second (VABS-II; Sparrow et al., 2005) and Third Edition (VABS-3; Sparrow et al., 2016). The Vineland-II was used at the preschool time point and Vineland-3 was used at the middle childhood time point. The adaptive measure will be subsequently referred to as Vineland-2/3. The Vineland-2/3 is a norm-referenced semi-structured interview. This interview is used to get information on the level of adaptive behavior across four domains: Communication (expressive, receptive, and written language), Daily Living Skills (self-care, domestic, and community skills), Socialization (interpersonal skills, leisure, and coping skills), and Motor Skills (gross and fine motor skills). Score across the four domains are combined to provide an

Adaptive Behavior Composite (ABC), which is then transformed to form a standard score. This norm-referenced composite score depicts the level of skills in adaptive behavior functioning. The Vineland-II and Vineland-3 have strong reliability and validity and has been widely used as a measure of adaptive skill acquisition in children with developmental disabilities. For the purpose of this study child overall adaptive behavior the ABC was reported for this study. Alpha reliabilities for the current sample are not available for the ABC.

Executive functioning. Applied EF was measured at the middle childhood time point (Time 2) using the Behavior Rating Inventory of Executive Function, Second Edition (BRIEF-2; Gioia et al., 2015). The BRIEF-2 is a measure of caregiver-reported applied EF. Caregivers answered behavioral statements (e.g., "Tries same approach to a problem over and over when it does not work.") using the terms "Never", "Sometimes", or "Often". Two validity scales are included: Negativity scale (i.e., measure of an unusually negative response style) and Inconsistency scale (i.e., measure of contradictory of unusual manner of responding). The use of the Negativity scale as a measure of validity for children with ASD is not recommended based on the focus on behaviors associated with rigidity, a core symptom of ASD (Blijd-Hoogewys et al., 2014). A composite scale (Global Executive Composite [GEC]) and three indices are included in the BRIEF-2: behavioral regulation ([BRI]; shift, emotional control), emotional regulation ([ERI]; shift, emotional control), and cognitive regulation ([CRI]; initiate, working memory, planning/organizing, task-monitor, organization of materials). Separate norms are provided for age and gender groups. T-scores are used for the composite scale, indices, and scales. Reliability and validity has been reported for this instrument, with

caregiver coefficient alpha values for index scores reported to fall above .90 (Gioia et al., 2015, p. 101). Child applied EF was reported using the GEC for this study. The coefficient alpha for the present study for the GEC was $\alpha = .97$.

Direct Child Measures

General cognitive ability. Cognitive ability was assessed during middle childhood (Time 2) using two variations of the Weschler Intelligence Scales. The Block Design, Vocabulary, Matrix Reasoning, and Similarities subtests of the Weschler Intelligence Scale for Children, Fifth Edition (WISC-V; Weschler, 2014b) was administered to the first 38 participants ($n = 38$) and the full Weschler Abbreviated Scales of Intelligence, Second edition (WASI-II; Weschler, 2011a) battery was administered to the remaining participants ($n = 55$). The change in measures was made due to a need to decrease the length of the clinical visit for the overall KBN study. A description of each measure is provided below as well as a description of the score conversion used to develop an equivalent score across both versions of the assessment used. Sample means comparisons by cognitive measure (WISC-V vs. WASI-II) can be found in Results. In the present study, the converted WASI-II score was used as a measure of cognitive ability for all participants given that no significant differences were found between child participant's overall cognitive and adaptive scores based on the cognitive measure used.

WISC-V. The WISC-V was initially used to assess general cognition. The Block Design, Vocabulary, Matrix Reasoning, and Similarities subtests of the WISC-V were selected based on their alignment to the WASI-II battery (see below). The WISC-V is a standardized, norm-referenced measure of cognition. A full range of cognitive tasks are included and are categorized into indexes measuring verbal comprehension (Verbal

Comprehension Index), visual spatial (Visual Spatial Index), fluid reasoning (Fluid Reasoning Index), working memory (Working Memory Index), and processing speed (Processing Speed Index). Index and full-scale intelligence quotient (FSIQ) are reported using standard scores. The WISC-V is considered a valid and reliable cognitive measure, with reliability coefficients for indices between .89 to .96 (Weschler, 2014b). WISC-V scores were converted and reported as WASI-II scores (see below).

WASI-II. To reduce cognitive assessment administration time, the WASI-II was used to assess general cognition for the majority of study participants. The WASI-II is a standardized, norm-referenced measure of cognition using an abbreviated battery of subtests (i.e.., Vocabulary, Similarities, Block Design, Matrix Reasoning) from the Weschler Intelligence Scales for Children-Fourth edition (WISC-IV; Weschler 2003) using updated child norms. These scales were chosen by test publishers due to their strong association with overall intellectual functioning. Cognition is measured using a Verbal Comprehension Index (VCI) and Perceptual Reason Index (PRI). Index and full-scale intelligence quotient (FSIQ) standard scores were be reported using standard scores. The WASI-II is considered a valid and reliable abbreviated cognitive measure, with reliability coefficients for all composites above .90 (Weschler, 2011b). General cognitive ability was reported by FSIQ with standard scores. Alpha reliabilities for the current sample are not available for the WASI-II FSIQ.

Score Conversion. The same four subtests were administered to all participants (i.e., Block Design, Vocabulary, Matrix Reasoning, and Similarities); however, norm groups varied based on the original cognitive measure (WISC-V, normed in in 2010; WASI-II, normed in 2013). Scores from participants tested using the WISC-V were

converted to WASI-II FSIQ scores based on a researcher-created score conversion accounting for the Flynn Effect. The Flynn Effect is an observed psychological phenomenon in which FSIQ scores rise over time for approximately .33 points per year (Trahan et al., 2014; Weiss et al., 2016). This effect has been well-studied, including direct investigations of Weschler cognitive measures over time (Weiss et al., 2016). Based on the most recent Flynn Effect measurement research, scores from participants who were tested using the WISC-V were adjusted by +1 to account for a 3-year difference in norm groups, at a +.33 point difference per year. The following score conversion steps were developed by the author (Barton) and primary KBN principal investigator (McIntyre): 1) convert WISC-V subtest raw scores to scale scores using the WISC-V test manual (Weschler, 2014a); 2) mathematically convert scale scores to T scores; 3) sum T scores for VCI (Vocabulary & Similarities), PRI (Block Design, Matrix Reasoning), & FSIQ (VCI and PRI) indices; 4) convert indices' T score sums using WASI-II manual (Weschler, 2011b), and 5) adjust all converted scores by +1 (3 years x .33 per year). Scores were converted for all participants (n = 38) who were tested using the WISC-V.

Autism symptoms. Behaviors consistent with ASD in middle childhood were measured using the ADOS-2 (Lord et al., 2012; Lord et al., 2009) by research assistants who were trained to research reliability standards. The ADOS-2 is a semi-structured observation measure in which examiners observe behaviors related to core autism symptoms (Lord et al., 2012). Administration lasts approximately 40 to 60 minutes and are comprised of carefully planned social interactions and communication opportunities. The ADOS-2 includes five modules (Toddler, 1-4). Modules were selected by the

examiner based on participant language level and development. Module 1, 2, and 3 were administered as a part of this study. Participant's behaviors were scored on a 4-point scale with 0 representing "no abnormality of type specified" and 3 representing "moderate to severe abnormality". Relevant items were divided into two symptom domains directly related to diagnostic criteria association with ASD (i.e., impairments in social communication and interactions, presences of RRBs): "Social Affect" and "Restricted and Repetitive Behaviors". The domains were summed for an algorithm overall Total Score. This score was compared to diagnostic cutoffs to determine whether the participant meets the criteria for "Autism", "Autism Spectrum" or "Nonspectrum". In addition, a Comparison score was provided based on the participant's age and Total Score. Comparison scores suggest autism severity on a scale of 1 to 10, with 1 indicating low severity and 10 indicating significant severity. Participant comparison scores were reported as a measure of ASD symptom severity. Internal consistency for all modules range from α =.74-.91 for the Communication and Social domains (i.e., SA) totals and α =.47 to .65 for the Stereotyped Behaviors and Restricted Interests domain (i.e., RRB) totals (Lord et al., 2012). For the current study, autism symptomology was reported for all participants using the Comparison score.

Executive functioning. Direct measures of attention and working memory during middle childhood were measured using the National Institutes of Health (NIH) Toolbox Cognition Battery ([NIHTB-CB]; Gershon et al., 2013; Weintraub et al., 2013; Zelazo et al., 2013). Two measures are used: Flanker Inhibitory Control and Attention Test (Flanker) & List Sorting Working Memory Test (List Sorting). Both measures were administered using the NIHTB-CB app (Glinberg & Associates, 2013).

Flanker. Attention was measured using the Flanker Inhibitory Control & Attention task (Glinberg & Associates, 2013). In Flanker, child participants were asked to indicate the left-right orientation of a central stimulus that is flanked by similar stimulus on the left and right (see Appendix). Trials were either congruent (i.e., flanking stimuli face the same direction as the target) or incongruent (i.e., flanking stimuli face the opposite direction as the target). Three different versions are available depending on child age (i.e., Ages 3-7, Ages 8-11, Age 12+) were used, with the primary difference between ages being the central stimulus (i.e., fish for children younger than 8, arrows for children ages 8 and above). The Flanker task includes 40 trials and generally takes 4 minutes to complete. Participants' accuracy and reaction time were initially reported using a score of 0 to 10. Final Flanker scores were reported as T scores from a nationally-normed, age-adjusted sample (Gershon et al., 2013). Alpha reliabilities for the current sample are not available for Flanker.

List Sorting. Working memory was measured using the List Sorting Working Memory test (Gershon et al., 2013). Visual (i.e., object picture) and oral (i.e., spoken name) stimuli were presented in a series using the NIHTB app (see Appendix). Participants repeated the stimuli to the examiner in order of size. List sorting includes two conditions. In the first condition, all stimuli were from one category. In the second condition, stimuli were presented from two categories. The number of items in each series increased per trial and the task was discontinued when two trials of the same length were failed. Listing Sorting typically took 7 minutes to complete. Scores were initially reported as total items correct across trials and were reported as a final "Total Score"

using a T score from a normative sample (Tulsky et al., 2014). Alpha reliabilities for the current sample are not available for List Sorting.

CHAPTER III

RESULTS

Analysis Overview

All statistical analyses were conducted in SPSS (version 26). Descriptive statistics, mean comparisons, bivariate correlations and hierarchical linear regressions were included in the analytic approach.

Power analyses. Two power analyses were conducted using G*Power. First, an a priori power analyses was conducted given the five regression variables and a p value of .05. The a priori power analysis indicated a sample size of 102 was needed to detect a small-to-moderate effect size of 0.21. Next, a post hoc power analysis was conducted with the final sample size of $n = 93$ and a two tailed alpha set to $p = .05$. The post hoc power analysis determined there was not sufficient power to detect a small to medium effect size ($r = .21$). Semi-partial correlations were then reported as a measure of effect size for this study due the lack of sufficient power. Findings were interpreted as clinically meaningful when statistically significant with $p < .05$ or when $sr > .21$.

Preliminary Analyses

Preliminary analyses were conducted to review the data and to check for missing data. Data were collected from 101 child participants. Eight participants completed caregiver questionnaires but did not participate in clinical visits. These participants were omitted from the final sample ($n = 93$) due to missing clinical data (i.e., demographic questionnaire, WASI-II, ADOS-2). Of the 93 participants, 59 completed the second clinical visit and contributed direct EF data. Direct measures of EF (i.e., Flanker, List Sorting) were missing for 34 child participants. These participants were not included in

regressions including direct EF data. Data from the final sample was then assessed for outliers and overall distribution.

Normality of distribution varied based on the variable of interest. In regards to child variables, child age was moderately, positively skewed with no severe outliers, z(skew) = 0.67 and z(kurtosis) = 0.45. Adaptive behavior assessed at preschool was approximately symmetrical with no severe skew or outliers, z(skew) = 0.08 and z(kurtosis) = -0.23. Adaptive behavior assessed at middle school was also approximately symmetrical with two potentially severe outliers (one positive, one negative), z(skew) = -0.02 and z(kurtosis) = 1.38. The distribution of applied/caregiver-reported EF was approximately symmetrical with no severe skew or outliers z(skew) = -0.43 and z(kurtosis) = -0.19. Both direct measures of EF were roughly symmetrical with no severe skew or outliers: Flanker, z(skew) = 0.22 and z(kurtosis) = -.18; List Sorting, z(skew) = .33 and z(kurtosis) = 1.76. The distribution of overall cognitive abilities was approximately symmetrical with one positive outlier, z(skew) = -0.41 and z(kurtosis) = -0.49. The severity of ASD symptoms was moderately, positively skewed with no severe outliers, z(skew) = 0.55 and z(kurtosis) = -1.19. Finally, annual household income was highly, positively skewed with one negative outlier, z(skew) = 1.46 and z(kurtosis) = 2.49. Transformations were not conducted on any variables of interest due to the lack of severe skew and outliers or due to expected skew based on the demographics of the population (i.e., ASD symptoms, income).

Demographic information. The sample size, means, standard deviations, and/or percentages for descriptive and demographic data for child and caregivers participants are presented in Table 1 and 2. At preschool child participants were, on average, 44.91

months (3.74 years) old (*SD* = 19.23; 1.60 years). At middle childhood child participants were, on average, 110.88 months (9.24 years) old (*SD* = 23.09 months; 1.92 years). The majority of the child participants were identified as white (94.63%) and male (78.52%). Caregiver demographics are reported for the middle childhood time point. Primary caregivers were on average 46.04 years old (*SD* = 5.91) and primarily identified as white (94.64%) and female (93.51%). About one third (35.50%) of the primary caregivers had completed an undergraduate degree or above. The average annual household income for this sample was $61,219.55 (*SD* = $42,440.15).

Table 1

Demographic Statistics for Children and Caregivers

Variable	*M(SD)*	*n(%)*
Child		
Preschool age (months)	44.91(19.23)	
Middle childhood age (months)	110.88 (23.09)	
Male		73 (78.52)
White		88 (94.63)
Primary caregiver		
Age (years)	46.04 (5.91)	
Female		88 (94.64)
White		87 (93.51)
With undergraduate degree or above		33 (35.50)
Annual income	$61,219.55 ($42,440.15)	

In order to participate in this study, child participants had to have been identified with DD or a disability in preschool. Child diagnostic characteristics in preschool and middle childhood are presented in Table 2. In preschool, child participants were primarily identified as having a speech delay (46.73%), ASD (33.74%), global developmental delay (10.92%), genetic condition/disorder (4.31%), or a delay categorized as "other" (4.42%). In middle childhood, the majority (84.86%) of child participants continued to carry diagnoses for DD or learning problems. The most commonly identified categories in middle childhood included ASD (39.82%), ADHD (31.26%), speech delay (28.01%), and DD (14.02%). In addition, 29.17% of child participants were identified as having a mental health condition in middle childhood. The most common mental health conditions identified in middle childhood included anxiety (24.73%), obsessive compulsive disorder (6.54%), conduct disorder/oppositional defiance disorder (4.32%), and depression (2.11%).

A new variable was created for diagnostic classification of ASD at the preschool and middle childhood time points. The variable of "community diagnosis" was conceptualized as caregiver report of medical diagnosis and/or school special education eligibility of ASD. Child participants were placed into two groups based on caregiver report: ASD and no ASD. Community diagnosis of ASD at the preschool and middle childhood time points is displayed in Table 2 and 3. A chi-square test was performed between preschool and middle childhood community diagnosis as well as between middle childhood community diagnosis and ADOS-2 cutoff scores (Autism/Autism Spectrum or Nonspectrum) in order to determine the relation between child diagnostic classifications of ASD. The results are reported in Table 3. The relation between

Table 2

Diagnostic Characteristics for Children at Preschool and Middle Childhood Time Points

Variable	*n*	%
Preschool primary diagnosis		
% speech delay	43	46.73
% ASD	31	33.74
% DD	10	10.92
% genetic condition	4	4.31
% other	5	4.42
Middle childhood primary diagnosis		
% ASD	37	39.82
% ADHD	29	31.26
% speech delay	26	28.01
% DD	13	14.02
% no delay or dx	14	15.50
Middle childhood mental health condition		
Anxiety disorder	23	24.73
Obsessive compulsive disorder	6	6.54
Conduct/oppositional defiant disorder	5	4.32
Depression	2	2.11
No mental health condition	66	70.93

preschool and middle childhood ASD community diagnosis was significant, $\chi^2(1) = 52.95, p < .001$. In addition, the relation between middle childhood ASD community diagnosis and ADOS-2 cutoff scores was also significant $\chi^2(1) = 37.73, p < .001$. The

relation between ASD community diagnosis across time was significant and was significantly related to direct observations of autistic-symptoms in middle childhood.

Table 3

Crosstabulation of Community ASD Diagnoses Across Time Points and ADOS-2 Cut-off Scores in Middle Childhood

	Community Diagnosis in Middle Childhood			
	ASD	No ASD	Total	χ^2
Community Diagnosis in Preschool				37.73**
ASD	26	5	31	
No ASD	12	50	62	
Total	38	55	93	
ADOS-2 in Middle Childhood				52.95**
Autism or Autism Spectrum	33	5	38	
Nonspectrum	4	51	55	
Total	37	56	93	

Note. *$p < .05$, **$p. < .01$.

Descriptive information on study variables of interest including the Vineland-2/3 ABC, BRIEF-2 GEC, Flanker, List Sorting, WASI-II FSIQ, and ADOS-2 Comparison scores are presented in Table 4. Child participant's adaptive behaviors were reported in the moderately low range in preschool ($M = 80.28$, $SD = 11.35$) and middle childhood ($M = 78.19$, $SD = 15.70$). Child participant's overall cognitive abilities were in the low average range ($M = 88.66$, $SD = 19.16$) in middle childhood. Caregivers rated their child's overall applied EF skills in the potentially clinically elevated range ($M = 67.78$,

SD = 11.58) in middle childhood. Child participant's performance on the EF Flanker measure was in the average range (*M* = 42.59, *SD* = 10.40) in middle childhood. Child participant's performance on the direct EF List Sorting measure was also in the average range (*M* = 42.49, *SD* = 11.25) in middle childhood. Finally, child participant's observed autism symptoms were in the low autism-related symptoms range (*M* = 4.09, *SD* = 3.27) in middle childhood; however, for children who had a community diagnosis of ASD, their observed autism symptoms were in the moderate autism-related symptoms range (*M* = 6.97, *SD* = 2.58).

Table 4

Descriptive Statistics for Variables in Preschool and Middle Childhood

Variable	*M*	*SD*
Adaptive behavior		
Vineland-II ABC - Preschool	80.28	11.35
Vineland-3 ABC - Middle childhood	78.19	15.70
Cognitive - Middle childhood		
WASI-II FSIQ	88.66	19.16
Applied executive functioning - Middle childhood		
BRIEF-2 GEC	67.78	11.58
Direct executive functioning - Middle childhood		
Flanker	42.59	10.40
List Sorting	42.49	11.25
Autism symptoms – Middle Childhood		
ADOS-2 Comparison score	4.09	3.27

Comparisons by cognitive measure. Preliminary comparisons related to cognitive measures are displayed in Table 5. Comparisons were conducted to identify any significant differences in the sample based on the cognitive measure used. Two independent sample *t*-tests were conducted to examine child overall cognitive and adaptive abilities by measurement group (i.e., WISC-V or WASI-II) in middle childhood. For overall cognitive abilities, there was no significant difference in FSIQ for child participants tested using the WISC-V and the WASI-II, $t(91) = -0.31$, $p = .42$. In addition, no significant difference in overall adaptive abilities was observed for child participants tested using the WISC-V compared to the WASI-II, $t(91) = -0.06$, $p = .27$. As no significant differences were found between child participant's overall cognitive and adaptive scores based on the cognitive measure used, the converted WASI-II score was used as a measure of FSIQ for all child participants.

Table 5

Comparison by Cognitive Measure in Middle Childhood

	WISC-V		WASI-II			
Variable	*M*	*SD*	*M*	*SD*	*t*-test	*p*
Overall FSIQ	87.92	20.63	89.16	18.25	-0.31	.42
Overall adaptive behavior	78.32	13.61	78.11	17.12	0.06	.27

Note. WISC-V ($n = 38$), WASI-II ($n = 55$)

Research Question 1: What are the relations between child characteristics and EF in children with DD?

The first research question was addressed by examining the results of a bivariate correlation analysis. Results of the bivariate correlations are presented in Table 6. Child

age was negatively correlated with ASD classification in preschool ($r = -.51, p < .001$), adaptive behavior in preschool ($r = -.27, p = .01$), adaptive behavior in preschool ($r = -.38, p < .001$), direct EF performance on the Flanker task in middle childhood ($r = .25, p = .05$) and positively correlated with autism symptoms in middle childhood ($r = .44, p < .001$). Child sex (being female) was significantly associated with lower overall cognitive abilities in middle childhood ($r = -.22, p = .04$). Child ASD classification in preschool was positively correlated with adaptive behavior in preschool ($r = .34, p < .001$) and middle childhood ($r = .32, p = . < .01$) as well as negatively correlated with lower autism symptoms in middle childhood ($r = -.66, p < .001$). Adaptive behavior in preschool was positively correlated with adaptive behavior in middle childhood ($r = .50, p < .001$) as well as direct EF performance on the Flanker task ($r = .27, p = .03$) in middle childhood. Adaptive behavior in preschool was negatively correlated with applied EF in middle childhood ($r = -.21, p = .04$) and autism symptoms in middle childhood ($r = -. 30, p < .01$). Child adaptive behavior in middle childhood was negatively correlated with applied EF in middle childhood ($r = -.48, p < .001$) as well as autism symptoms in middle childhood ($r = -.31, p < .01$) and positively correlated with overall cognitive abilities in middle childhood ($r = .53, p < .001$). Caregiver-reported/applied EF in middle childhood was negatively correlated with direct EF performance on the List Sorting task ($r = - .26, p = .05$) as well as overall cognitive abilities ($r = -.21, p = .04$) and positively correlated with autism symptoms in middle childhood ($r = .23, p = .03$). Child performance on the Flanker task was positively correlated with overall cognitive abilities ($r = .26, p = .04$).

Table 6

Bivariate Correlations for Child Variables of Interest

Variable	1	2	3	4	5	6	7	8	9	10
1. T2 age	-									
2. Child sex	.03	-								
3. T1 ASD diagnosis	-.51**	.13	-							
4. T1 VABS	-.27**	-.02	.34**	-						
5. T2 VABS	-.38**	-.10	.33**	.50**	-					
6. T2 BRIEF-2: GEC	.06	-.13	-.15	-.21*	-.48**	-				
7. T2 Flanker	-.25*	-.01	.18	.27*	.21	-.17	-			
8. T2 List sorting	.24	-.03	.03	-.05	.12	-.26*	.02	-		
9. T2 WASI: FSIQ	.01	-.22*	.13	.38**	.53**	-.21*	.26*	.24	-	
10. T2 ADOS-2 comparison score	.44**	-.18	-.66**	-.30**	-.31**	.23*	-.16	-.11	-.17	-

Note. *$p < .05$, **p. <.01. T1 = Time 1, preschool; T2 = Time 2, middle childhood.

Research Question 2: Do measures of adaptive functioning and community diagnosis in preschool predict unique variance in applied EF in middle childhood for children with DD?

A hierarchical linear regression analysis was conducted to answer the second research question. Child demographics (sex, age) were entered in Step 1 followed by adaptive behavior and child diagnostic categorization in preschool in Step 2. See Table 7 for results. The relation of child demographic characteristics on applied EF in middle childhood was not significant $F(2, 88) = 0.84$, $p = .44$, and accounted for 2% of the overall variance in applied EF. The addition of preschool diagnosis ($sr = -.09$) and preschool adaptive behavior ($sr = -.19$) did not add to the model and were not meaningful predictors of applied EF after accounting for child demographic variables. Preschool adaptive behavior and diagnostic categorization predicted an additional 5% (overall model $R^2 = .07$) of the variance in applied EF; however, the results at Step 2 were also not statistically significant $F(4, 86) = 1.50$, $p = .21$.

Research Question 3: Do measures of adaptive functioning and community diagnosis in preschool predict unique variance in direct measures of EF in middle childhood for children with DD?

Two hierarchical linear regression analysis were conducted to answer the third research question, one for the direct Flanker measure and one for the direct List Sorting measure. Again, child demographics were entered in Step 1 followed by adaptive behavior and child diagnostic categorization in preschool in Step 2. Results are presented in Table 8 and 9.

Table 7

Summary of Hierarchical Regression Analysis for Variables Predicting Applied EF in Middle Childhood

Variable	*Unstandardized B*	*SE β*	*Standardized β*	*Semi-Partial r*	*t*	ΔR^2	*F*
Step 1						**.02**	**0.84**
Age	0.03	0.05	-0.12	.06	0.06		
Sex	-0.51	0.44	0.06	-.12	-0.12		
Step 2						**.07**	**1.50**
Age	-0.02	0.44	-0.11	-.03	-0.04		
Sex	-0.44	0.44	-0.04	-.11	-0.11		
Preschool diagnosis	-2.27	3.09	-0.09	-.07	-0.09		
Preschool adaptive behavior	-0.20	0.12	-0.19	-.18	-0.19		

Note. *$p < .05$, **$p < .01$, ***$p < .001$.

In regards to the direct Flanker measure, child demographics added in Step 1 accounted for 6% of the unique variance in direct EF measures but were not statistically significant $F(2, 60) = 1.98, p = .15$. In Step 1, child sex ($sr = -.25$) was a meaningful predictor of child performance on Flanker; however, this relation was no longer significant ($sr = -.02$) when additional variables were added in Step 2. When child adaptive behavior and diagnostic classification in preschool was added, an additional 4% (overall model $R^2 = .10$) of the unique variance in direct performance on the Flanker measure was accounted for by the model. Adaptive behavior ($sr = .16$) and diagnostic classification ($sr = .02$) in preschool did not significantly contribute to the model. Results including child adaptive behavior and diagnostic classification in preschool were not statistically significant $F(4, 58) = 1.52, p = .21$.

Child demographics accounted for 6% of the variance of performance on the List Sorting measure in Step 1. Step 1 results were not statistically significant, $F(2, 58) = 1.77, p = .18$. . In Step 1 ($sr = .23$) and Step 2 ($sr = .27$) of the model, age was a meaningful predictor of child performance on the List Sorting measure. Preschool diagnostic classification ($sr = .15$) and adaptive behavior ($sr = .02$) were not meaningful predictors of child performance on List Sorting in middle childhood. The addition of child adaptive behavior and diagnostic classification in preschool accounted for an additional 2% (overall model $R^2 = .08$) of the unique variance in direct performance on the List Sorting measure; however, these results were not statistically significant, $F(4, 56) = 1.29, p = .29$.

Research Question 4: Do cognition and ASD symptoms explain additional unique variance in applied EF after controlling for adaptive functioning and community

Table 8.

Summary of Hierarchical Regression Analysis for Variables Predicting Direct Performance on Flanker in Middle Childhood

Variable	*Unstandardized B*	*SE β*	*Standardized β*	*Semi-Partial r*	*t*	ΔR^2	*F*
Step 1						**.06**	**1.98**
Age	-0.12	0.06	-0.25	-.02	-1.9		
Sex	-0.06	0.47	-0.02	-.25	-0.13		
Step 2						**.10**	**1.52**
Age	-0.07	0.07	-0.15	-.12	-0.97		
Sex	-0.07	0.47	-0.20	-.02	-0.16		
Preschool diagnosis	0.57	3.31	0.03	.02	0.17		
Preschool adaptive behavior	0.18	0.14	0.20	.16	1.32		

Note. *$p < .05$, **$p < .01$, ***$p < .001$.

Table 9.

Summary of Hierarchical Regression Analysis for Variables Predicting Direct Performance on List Sorting in Middle Childhood

Variable	*Unstandardized B*	*SE β*	*Standardized β*	*Semi-Partial r*	*t*	ΔR^2	*F*
Step 1						**.06**	**1.77**
Age	0.13	0.06	0.24	.23	1.87		
Sex	-0.11	0.51	-0.03	-.02	-0.21		
Step 2						**.08**	**1.28**
Age	0.17	0.08	0.33	.27	2.17		
Sex	-0.21	0.52	-0.05	-.05	-0.40		
Preschool diagnosis	4.27	3.62	0.17	.15	1.18		
Preschool adaptive behavior	0.03	0.15	0.02	.02	0.16		

Note. *$p < .05$, **$p < .01$, ***$p < .001$.

diagnosis for children with DD?

One hierarchical linear regression analysis was conducted to answer the fourth research question. Child demographics were entered in Step 1 followed by adaptive behavior and child diagnostic categorization in preschool at Step 2. Child cognitive abilities and ASD symptoms in middle childhood were added to Step 2. These additional variables were not added as a new step due to the non-significant results reported for research question 2. Results are presented in Table 10. Child demographics accounted for 1% of the variance in applied EF and were not statistically significant, $F(2, 85) = 0.55$, $p = .60$. The addition of middle childhood overall cognitive abilities ($sr = -16$) and ASD symptoms ($sr = .13$) were not additional, meaningful predictors of child applied EF in middle childhood. When child adaptive behavior and diagnostic classification in preschool as well as cognitive abilities and ASD symptoms were added to the model, an additional 9% (overall model $R^2 = .10$) of the variance in applied EF was accounted for; however, these results were not statistically significant, $F(6, 81) = 1.66$, $p = .14$.

Research Question 5: Do cognition and ASD symptoms explain additional, unique variance in direct EF in middle childhood after controlling for adaptive functioning and community diagnosis in preschool for children with DD?

Two hierarchical linear regressions were conducted using the same procedures outlined in research question 3 with the addition of child cognitive abilities and ASD symptoms in middle childhood in Step 2. See Table 11 & 12 for results. When examining variables predicting direct performance on the Flanker measures, 6% of the unique variance was accounted for, but not significant, by child demographics, $F(2, 58) = 1.89$, $p = .16$. Child age was a meaningful predictor ($sr = .25$) of child direct performance on

Table 10.

Summary of Hierarchical Regression Analysis for Variables Predicting Applied EF in Middle Childhood with the Addition of Cognitive Abilities and Symptoms of ASD

Variable	*Unstandardized B*	*SE β*	*Standardized β*	*Semi-Partial r*	*t*	ΔR^2	*F*
Step 1						**.01**	**.55**
Age	0.03	0.05	0.06	-.09	0.56		
Sex	-0.39	0.45	-0.09	.06	-0.85		
Step 2						**.10**	**1.66**
Age	-0.01	0.07	-0.01	-.01	-0.11		
Sex	-0.34	0.46	-0.08	-.08	-0.08		
Preschool diagnosis	0.10	3.67	0.04	.01	0.03		
Preschool adaptive behavior	-0.09	0.13	-0.09	-.08	-0.75		
Middle childhood cognitive abilities	-0.12	0.08	-0.19	-.16	1.56		
Middle childhood ASD symptoms	0.62	0.51	0.17	.13	1.20		

Note. *$p < .05$, **$p < .01$, ***$p < .001$.

Flanker in Step 1 but not when other variables were added to the model in middle childhood. The addition of child adaptive behavior and diagnostic classification in preschool as well as cognitive abilities and ASD symptoms in middle childhood accounted for an additional 8% (overall model $R^2 = .14$) of the variance. Results of the overall model were not statistically significant, $F(6, 54) = 1.43$, $p = .22$. The addition of middle childhood cognitive ability ($sr = .21$) was a meaningful predictor of Flanker abilities; however, the relation was not significant for middle childhood ASD symptoms ($sr = .04$).

Child demographics accounted for 6% of the overall variance in performance on the List Sorting measure. Results of Step 1 from the List Sorting measure were not statistically significant, $F(2, 56) = 1.92$, $p = .16$. Once child adaptive behavior and diagnostic classification in preschool as well as cognitive abilities and ASD symptoms were added in Step 2, an additional 10% (overall model $R^2 = .16$) of the variance in on the List Sorting measure was accounted for; however, these results were not statistically significant, $F(6, 52) = 1.70$, $p = .140$. Age was again a meaningful predictor of child direct performance of the List Sorting task at Block 1($sr = .25$) and Block 2 ($sr = .37$). The addition of cognitive abilities ($sr = .13$) and ASD symptoms ($sr = -.18$) Block 2 did not contribute meaningfully to the model in Step 2.

Post hoc Analysis

Based on the null results of research questions 2-5 and the significant correlations from question 1a, a post hoc analysis was run to examine the impact of middle childhood adaptive behavior on applied EF in child participants. The conceptual model for the post hoc analysis is featured in Figure 2. The impact of middle childhood adaptive behavior

Table 11.

Summary of Hierarchical Regression Analysis for Variables Predicting Direct Performance on Flanker in Middle Childhood with the Addition of Cognitive Abilities and Symptoms of ASD

Variable	*Unstandardized B*	*SE β*	*Standardized β*	*Semi-Partial r*	*t*	ΔR^2	*F*
Step 1						**.06**	**1.89**
Age	-0.12	0.60	-0.25	-.25	-1.94		
Sex	-0.07	0.48	-0.19	-.02	-.15		
Step 2						**.14**	**1.43**
Age	-0.10	0.08	-0.20	-.16	-1.29		
Sex	0.06	0.50	0.02	.01	0.11		
Preschool diagnosis	1.24	3.94	0.06	.04	0.31		
Preschool adaptive behavior	0.09	0.16	0.10	.07	0.58		
Middle childhood cognitive abilities	0.15	0.09	0.23	.21	1.64		
Middle childhood ASD symptoms	0.18	0.60	0.05	.04	0.30		

Note. $*p < .05$, $**p < .01$, $***p < .001$.

Table 12.

Summary of Hierarchical Regression Analysis for Variables Predicting Direct Performance on List Sorting in Middle Childhood with the Addition of Cognitive Abilities and Symptoms of ASD

Variable	*Unstandardized B*	*SE β*	*Standardized β*	*Semi-Partial r*	*t*	ΔR^2	*F*
Step 1						**.06**	**1.92**
Age	0.13	0.07	0.25	.25	1.92		
Sex	-0.18	0.51	-0.05	-.05	-0.35		
Step 2						**.16**	**1.70**
Age	0.19	0.08	0.37	.29	2.29		
Sex	-0.34	0.54	-0.09	-.08	-0.64		
Preschool diagnosis	2.10	4.15	0.09	.06	0.51		
Preschool adaptive behavior	-0.03	0.16	-0.03	-.02	-0.19		
Middle childhood cognitive abilities	0.12	0.11	0.15	.13	1.06		
Middle childhood ASD symptoms	-0.93	0.64	-0.26	-.18	-1.45		

Note. *$p < .05$, **$p < .01$, ***$p < .001$

on direct measures of EF was not examined as the variables of interest were not significantly correlated (see Table 6).

To examine the impact of middle childhood adaptive behavior on applied EF in middle childhood, a hierarchical linear regression was conducted. Similar to research questions 2-5, child demographics were added in Step 1 and child diagnostic category in preschool was added at Step 2. In the post hoc analysis, middle childhood adaptive behavior was added in the place of preschool adaptive behavior during Step 2. Results are presented in Table 13. Child demographics accounted for 2% of the variance in applied EF and the results were not statistically significant $F(2,88) = 0.84$, $p = .44$. The addition of child diagnostic category in preschool and adaptive behavior in middle childhood accounted for an additional 24% (overall model $R^2 = .26$) of the variance of applied EF in middle childhood. The addition of middle childhood adaptive behavior contributed meaningfully ($sr = -.48$) to the model in Step 2. The results of the final model were statistically significant, $F(4, 86) = 7.59$, $p < .001$, indicating middle childhood adaptive functioning may impact current applied EF.

Figure 2

Post hoc Conceptual Model

Table 13.

Summary of Post-Hoc Hierarchical Regression Analysis for Variables Predicting Applied EF

Variable	*Unstandardized B*	*SE β*	*Standardized β*	*Semi-Partial r*	*t*	ΔR^2	*F*
Step 1						**.02**	**0.84**
Age	.03	.05	.06	.06	.54		
Sex	-.51	.44	-.12	-.12	-1.17		
Step 2						**.26*** **	**7.59**
Age	-.07	.06	-.14	-.12	-.128		
Sex	-.60	.39	-.14	-.14	-1.51		
Preschool diagnosis	-1.13	2.71	-.05	-.03	-.42		
Middle childhood adaptive behavior	-.38	.08	-.51	-.48	-5.14		

Note. *$p < .05$, **$p < .01$, ***$p < .001$

CHAPTER VI

DISCUSSION

Summary of Results

The purpose of this exploratory study was to investigate early childhood variables that may impact future EF for children previously identified with DD. Specifically, this investigation focused on the power of preschool (i.e., Time 1) adaptive behavior as well as diagnostic classification to applied and direct measures of EF in middle childhood (i.e., Time 2). Based on previous research in children with neurodevelopmental disabilities (i.e., ADHD, ASD), adaptive behavior and the presence of ASD was expected to impact both applied and direct EF. This investigation with an understudied population of 93 children previously identified with DD reversed the direction of variables of interest (i.e., adaptive behavior as a predictor of EF) from previous studies. First, relations among child variables of interest were examined. Then, the predictive power of preschool adaptive behavior and diagnostic category was measured for current both direct and applied EF. Finally, the additional impact of current child cognitive abilities and ASD symptom severity on current EF was investigated after controlling for child adaptive behavior and diagnostic category. Based on the results of the a priori research questions, a single post hoc analysis was conducted examining the impact of middle childhood adaptive behavior and preschool diagnostic classification on current EF in children with DD.

In regards to research question 1, significant relations were found between middle childhood applied EF and both preschool and middle childhood adaptive behavior. Direct EF in middle childhood was significantly related to child gender and current adaptive

functioning but was not significantly related to variables such as preschool adaptive behavior or diagnosis as hypothesized. Among the variables examined in research questions 2 through 5, none emerged with significant predictive value or effect size for direct or applied EF in middle childhood The hypothesized results of preschool diagnostic category and adaptive behavior significantly explaining unique variance in direct and applied EF in middle childhood were not supported. These results were also true when the variables of middle childhood cognitive abilities and ASD symptoms were added to the model. The non-significant results for both measures of EF indicate there may be unexplored factors related to overall child EF, such as intervention history, additional medical or mental health diagnoses as well as factors like medication use.

Finally, a post hoc analysis was conducted that examined the power of middle childhood adaptive behavior and preschool diagnostic classification on middle childhood applied EF. Results indicated adaptive behavior in middle childhood accounted for an additional 24% of the variance in applied EF in middle childhood after accounting for child demographic variables and preschool diagnostic classification. This finding is consistent with previous research investigating the impact of caregiver-reported/applied EF on adaptive functioning. Prior investigations have focused on correlation between applied EF and adaptive functioning in children with ASD (e.g., Kenny et al., 2019) and ADHD (e.g., Balboni et al., 2017). In particular, the present study's post hoc findings are consistent with Kenny et al.'s (2019) examination of the positive correlations between adaptive behavior and EF in adolescent participants with ASD. While these results support previous research on the corresponding relationship between concurrent

caregiver-reported adaptive behavior and EF, the results do not support general study aims focused on identifying predictive variables across time points.

Implications

The primary findings of this study suggest there is a strong, concurrent relation between caregiver-reported EF and caregiver-reported adaptive behavior assessed in middle childhood for children with DD. This finding supports previous literature on the consistency of caregiver-reported measures at the same time point (Barbosa & Gavião, 2012; Miller et al., 2017). Specifically, both caregiver-reported measures asked caregivers to report on applied behaviors, that is, behaviors the child performed on a daily basis in home and community contexts. While the BRIEF-2 specifically asked caregivers to report on behaviors associated with overall EF, many of the items directly related to adaptive behaviors measured using the Vineland-3 (e.g., ability to follow multi-step directions, attention span for preferred and non-preferred tasks) overlap conceptually with applied EF items. Not surprisingly, both of these caregiver-reported measures were significantly correlated in this sample. Caregiver-reported adaptive behavior assessed in middle childhood explained unique variance in caregiver-reported EF after accounting for child characteristics and diagnostic classification in preschool. The results of the post-hoc analysis were expected based on the previous literature examining caregiver rating scales as well as the correlation between applied measures.

In contrast, a positive, significant relation between preschool adaptive behavior and EF measured in middle childhood through direct or caregiver-report was not found. This indicates middle childhood EF was impacted by other, unidentified, variables during the preschool time period for this sample. Previous research has investigated the

predictive power of early EF on later behaviors, such as cognition and adaptive behavior. The findings of this research do no support the directional hypothesis that adaptive behavior impacts future EF in this sample. Given the underpowered results and small effect sizes, it is still unclear is this relationship exists in the DD population. This relationship was not observed in the study sample.

Child participants in this study were all previously identified with DD in early childhood. In middle children, the majority of participants were identified by their caregivers as meeting criteria for a disability. Child cognitive and adaptive abilities ranged widely within this sample, with some participants scoring in the very low or impaired range and others scoring in the superior range. The sample of this study presented with a broad range abilities; however, the average child adaptive and cognitive scores were in the below average range. The sample distribution of diagnostic categorization and child ability level were varied for this sample but match previously reported categories for DD (Boyle et al., 2011; Rosenburg et al., 2008). Given the lack of research on children with DD, especially children with DD in middle childhood and adolescence, it is still unknown how this sample relates to the population of children with DD.

Based on research with children with neurodevelopmental disabilities such as ADHD and ASD, diagnostic classification and adaptive behavior were expected to impact EF (e.g., Balbino et al., 2017; Kenny et al., 2019; Semrud-Clikeman et al., 2010). However, much is still unknown on the relation between these variables as well as the timing of impact. The results of this study provide evidence for strong associations between adaptive behavior and EF at the same timepoint. To date, longitudinal research

has not identified variables that predict future EF in this population. Again, child cognitive and adaptive variables have been reported as impacting future EF in children with ASD but this relation has not yet been observed in children with DD (e.g., Kenny et al., 2019; Pugliese et al., 2016). The results of this study do not support these hypothesis that past adaptive behavior and diagnosis impact future EF; however, additional research is needed in order to measure the true expected distribution and effect with heterogenous population.

The sample included in this study was measured across two different developmental periods: early and middle childhood. Significant developmental changes occur between early childhood (birth to age eight) and middle childhood (age eight to age twelve). The developmental changes between early and middle childhood are marked not only by physical and social-emotional growth but significant changes in cognitive processes. Most notably, middle childhood is characterized by changes in cognitive skills such as the ability to organize, integrate, and process information (Glowiak & Mayfield, 2016). This differs from cognitive milestones in early childhood where children gain language skills and begin to demonstrate understanding of basic verbal and non-verbal concepts. Changes in specific EF processes, such as working memory and inhibition, are hypothesized during middle childhood; however, descriptive research in this area is limited (Feinstein, & Bynner, 2004; Glowiak & Mayfield, 2016; Xu et al., 2013). Changes in cognitive abilities in children with DD has been measured in early childhood, specifically related to measures of disability severity (e.g., diagnostic characteristics, adaptive behavior; Kenny et al., 2019). The majority of research on cognition in middle childhood has focused on the predictive power of EF on adolescent variables, such as

problem behavior, overall cognitive abilities, and academic success (e.g., Charman et al., 2006; Miller & Hinshaw, 2009). The results of the present study align with previous research describing cognitive and EF abilities in children with ASD in middle childhood. The inclusion of multiple direct and applied EF measures builds upon past studies and adds to the descriptive literature on EF in middle childhood. Middle childhood continues represent and under-researched developmental period with preliminary cognitive investigations reporting changes in EF related to future cognitive performance and past adaptive abilities.

The results of this research provide direction for clinicians and families with children with DD. While the direction and strength of relations in preschool variables on EF in middle childhood are still unknown for the DD population, it is undeniable that there are associations between child characteristics and EF. Understandably, applied EF is related to adaptive behaviors; however, the directionality the strength is not yet known. Caregiver and practitioners should continue to focus on interventions that applied behaviors. For those concerned with EF in children with DD, this may mean interventions that specifically target common EF constructs such as attention and memory in addition to adaptive behavior. The combination of adaptive and applied EF behaviors represent rich intervention targets as both are considered malleable, unlike other constructs such as diagnostic categorization. Adaptive behavior and EF are intertwined for children with DD. Without additional information to support directionality and strength, caregiver and practitioners would be prudent to identify on interventions that provide dual focus on adaptive behavior and EF in applied contexts.

Limitations

There are several limitations within the current study that should be considered for future research on EF with children with DD. First, there are limits of the generalizability of study results based on the demographics of the sample population. The sample population was primarily comprised of white, male child participants in a specific geographic location. The results of the present study may not generalize to sample drawn from different geographic region and/or participants with different racial, ethnic, or clinical backgrounds. While the heterogenous diagnostic participant make-up was also a strength of the study, when considering the lack of research on children with DD, the wide range of child abilities and behavioral characteristics may also limit the application of findings to both clinical and TD populations.

The overall sample size also limits the results of this study. The overall sample size of 93 is relatively small and resulted in an underpowered-study. The lack of power due to sample size limited the analytic plans. Measures of effect size were modest in this sample for all analyses other than post-hoc regressions. This implies that even with sufficient power, the results of this study may have still been statistically non-significant.

An additional limitation of this study is related to the measurement of EF. EF is a wide-ranging construct and is typically measured using specific, neuropsychological tasks by construct or caregiver- and self-reports of applied EF concepts. This study included two direct measures of EF. While the Flanker and List Sorting tasks were conceptualized as "direct EF" for the purpose of the study, these tasks only represented two specific EF concepts (i.e., inhibition/attention, working memory) and are not designed to measure EF as a whole. Finally, these tasks were completed by a fraction of

the sample participants, further decreasing potential power for the statistical analyses related to direct EF.

In addition, the only significant statistical results (i.e., post-hoc regression) relied primarily on two caregiver-reported measures assessed at the same time point. Caregiver-reports of child behaviors at the same time point are typically associated with each other for similar constructs (e.g., Barbosa, & Gavião, 2012) but are not always consistent with direct observations or measures of the same behavior (e.g., Miller et al., 2017). Future research interested in the specific relationship between adaptive functioning and applied EF in children should consider direct measures of constructs in addition to caregiver-rating scales. Thus, the results of the study are limited in their interpretation and applicability within the context the sample characteristics and related statistically procedures as well as study measures.

Future Directions

There are several directions and variables to consider for future research in the examination of EF in children with DD. As noted in the limitations, the construct of EF can be difficult to study and is rarely fully measured using direct or indirect measures. Research on EF should clearly denote the dimensions of EF of interest and select measures based on the justification behind the study. Future examinations could include both direct and indirect measures; however, authors should expect differences between measures that rely on performance vs. caregiver- or self-report. The majority of research linking EF to adaptive behavior and interventions in children with ASD has relied on applied/caregiver-reported EF. While we do not yet know if this is the same for the DD

population, researchers could consider similar caregiver-reported variables of interest when looking to provide specific home and community-based recommendations.

Future research into the role of EF in children with DD should continue to clearly define the author's conceptualization of DD as well as the time period of the child's DD label. The behavioral presentation of DDs are wide ranging. The severity and prognosis of DD relays heavily on the developmental stage of the participant in question. For example, many children initially identified with DD during early childhood no longer carry the classification into middle childhood or adolescence. Children previously diagnosed with DD may be later identified with a neurodevelopmental or mood disorder; however, many do not meet diagnostic classification for any disorder later in life. The heterogeneity of the DD population is both a strength and a limitation for DD research. This population is wide-reaching and therefore relevant for many children, families and practitioners. However, the eclectic presentation of delays limit generalizability of this classification if not clearly defined.

Research on children with DD should be thoughtful in the developmental stage and time frame of focus. Examinations of child variables in early childhood may impact guidance on the prevention and early intervention whereas investigations of later childhood and adolescence could focus on the predictive power of early variables or outcomes associated with prior behavioral presentations. Significant development across domains occurs between early childhood and middle childhood. Changes in development for children with DD are hypothesized to rely on a wide range of internal and external variables. Future research may continue to focus on possible mediating/moderating factors on general development in children with DD during key developmental periods.

Based on the results of this study and the discussion thus far, additional research is needed to investigate the role of EF in important outcomes of interest for children with DD but in the population at large. Are the mechanisms responsible for explaining associations between EF and important outcomes the same for children with DD? Suggestions for future research includes continued examination of the distribution of EF, both applied and direct, in children with DD. Additional investigations could be strengthened by multiple time points in order to identify clear predictors of EF as well as the identification of moderator/mediators of the relation between EF and child diagnostic characteristics, such as social and communication variables.

Conclusion

Children with DD belong to a heterogenous group that may or may not experience disability later in life. In order to provide targeted and meaningful intervention, it is important to identify child variables implicated in future functioning for this group. The current study found significant associations between adaptive behavior and applied EF assessed in middle childhood. Contrary to study hypotheses, child diagnostic classification and adaptive behavior in preschool did not predict applied or direct EF in middle childhood. Only when concurrent adaptive behavior was considered did the relation between adaptive behavior and applied EF in middle childhood become clinically meaningful. While much is still to be learned about factors that predict and impact EF in children with DD, the current study did confirm previous research on caregiver-reported measures of EF in children with ASD or ADHD. Much is still unknown regarding variables predicting EF in middle childhood for children with DD. This construct is understudied in the DD population and additional research is needed on not only

variables related to EF but on the directionality of variables and developmental period of interest. Future research should continue to extend exploratory work on the construct of EF in children with DD based on the developmental period as well as the measurement of EF.

APPENDIX

Direct EF Measures

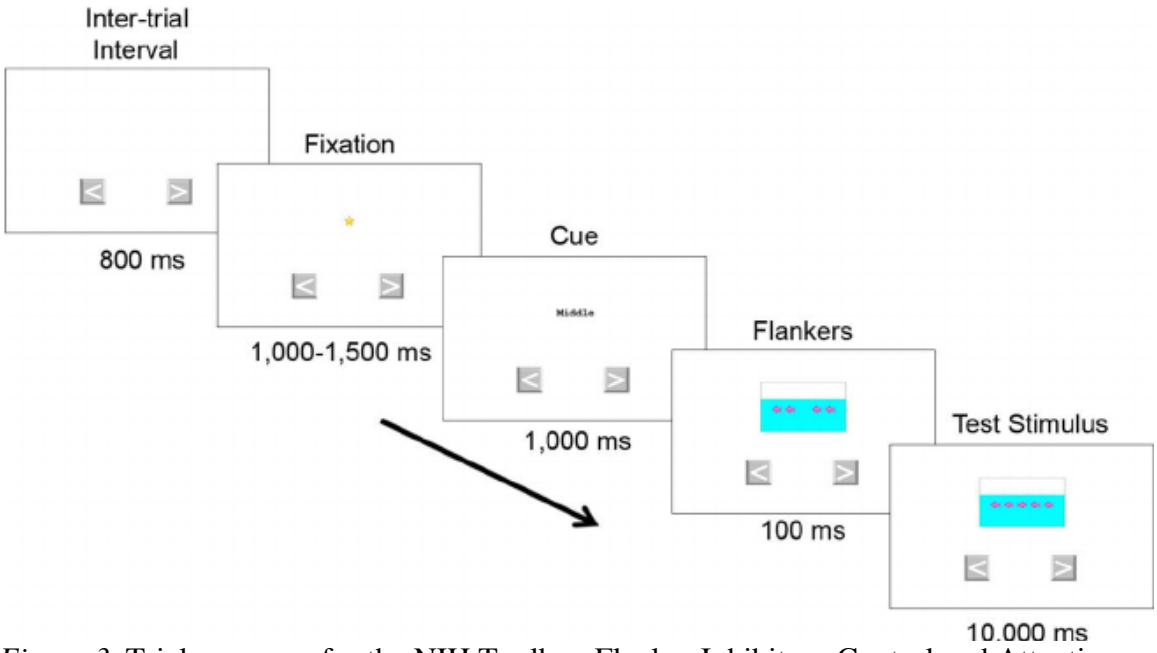


Figure 3. Trial sequence for the NIH Toolbox Flanker Inhibitory Control and Attention Test (fish block). All NIH Toolbox-related materials are ©2012 Northwestern University and the National Institutes of Health. In Zelazo et al. (2014, p. 624).

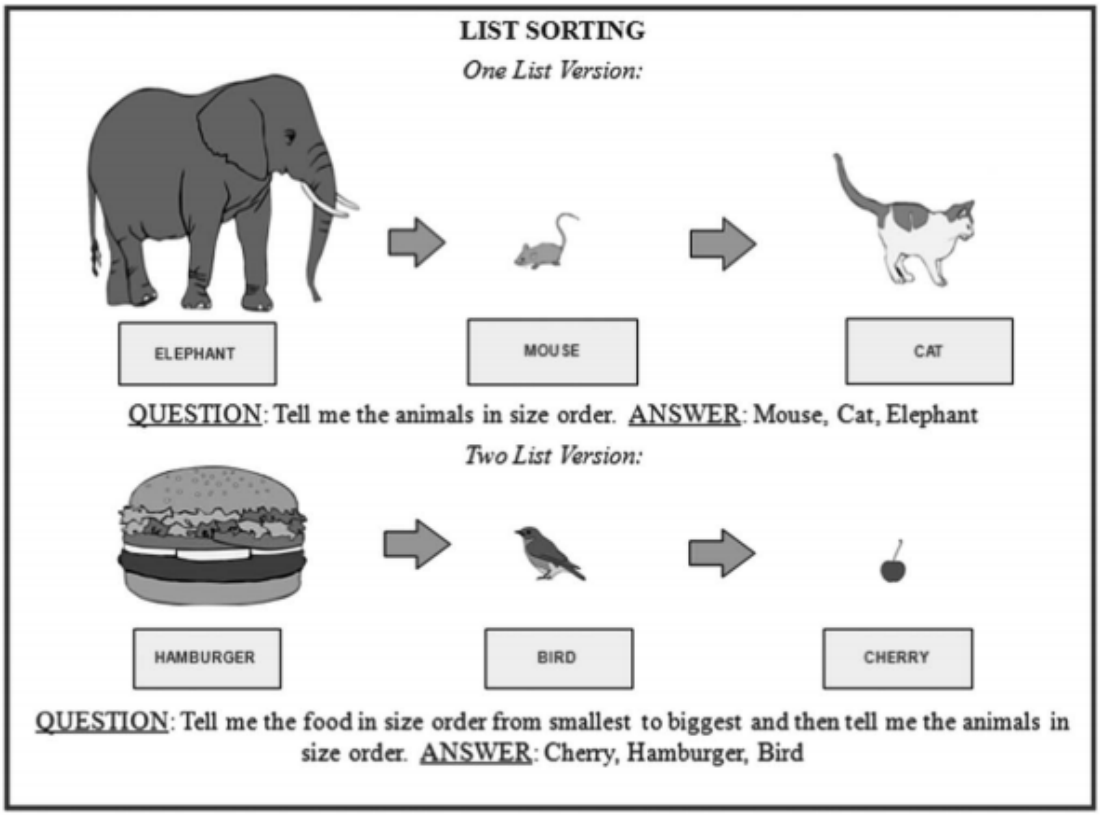


Figure 4. Examples of One-List and Two-List List Sorting Task. 1-List List Sorting requires participants to sequence items according to a single category, whereas 2-List List Sorting requires sequencing that involves an alternation between two different categories. The above is a sample NIH Toolbox List Sorting Test item. All NIH Toolbox-related materials are ©2012 Northwestern University and the National Institutes of Health. In Tulsky et al., 2014 (p. 602).

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