EXECUTIVE FUNCTION IN THE PRESCHOOL PERIOD: INSIGHTS ON DEVELOPMENTAL DISORDERS

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*We also certify that written approval has been obtained for any proprietary material contained therein.
I dedicate this thesis to my loving family and soon to be husband. Without your patience, assistance, and encouragement, this pursuit would have never been possible.
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The importance of executive function (EF) skills for optimal cognitive, behavioral, and emotional development is widely accepted. Researchers have suggested that deficits in EF may mediate many of the impairments seen in developmental disorders that emerge in childhood, such as attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), and specific language impairment (SLI). However, given the overlap in symptom presentation during the preschool period, the differential pattern of EF impairment coinciding with the specific diagnosis is not as well understood. Investigation of the pattern of EF strengths and weaknesses in preschool children with developmental disorders has been of interest. Traditional multivariate profile means analyses using the Behavior Rating Inventory of Executive Function – Preschool Version (BRIEF-P; Gioia, Espy, & Isquith, 2003) revealed distinct patterns based on diagnosis in the preschool children. This study aims to determine whether the mean profiles for each group adequately represent diagnostic categories in a preschool population using exploratory hierarchical cluster analysis (HCA). HCA techniques group participants based on similarity of pattern shape and means, resulting in clusters of homogeneous groups independent of diagnostic grouping. Eighty-two children are included in the analyses: 57
diagnosed with developmental disorders (SLI: n=18; ADHD: n=21, ASD: n=18), and 25 typical controls. Following HCA methods, a 4-cluster solution was retained with each of the four diagnostic groups showing predominant membership across one of the clusters. Cluster 1 evidenced normative EF skills, Cluster 2 indicated EF impairments in cognitive domains, Cluster 3 demonstrated moderate EF impairments in specific behavioral and cognitive domains, and Cluster 4 revealed the most severe impairments across all EF domains. Separate parent report measures also reveals differential patterns of language, behavioral, and socioemotional functioning across the clusters. Increasing our understanding of EF profiles can provide important information for improving the current classification system for preschoolers with developmental disorders and aid in the development of more efficacious early intervention programs.
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Executive Function in the Preschool Period: Insights on Developmental Disorders

Although a plethora of research has explored the construct of executive function (EF), definitional and measurement consensus is lacking. Disagreement regarding whether EF is a one-dimensional or a multidimensional construct abounds. Support for EF as a unitary construct is mixed. In a one-dimensional framework, EF is often depicted as a global system with no discernable components that adapts to varying cognitive and task-relevant demands (Duncan & Miller, 2002; Duncan & Owen, 2000). In contrast, other researchers contend that EF is composed of dissociable domains, with factor analytic data providing evidence in support of this proposition (Pennington, 1997; Welsh, Pennington, & Groisser, 1991). Researchers who support EF as a multidimensional construct depict the EF framework as comprised of independently functioning, yet interrelated EF domains. Proposed independent domains include working memory used to temporarily store and process information (e.g. Baddeley, 2012), inhibition used to home selective attention (e.g. Barkley, 1997; Diamond, 2013), and set-shifting used to adapt to changing task demands (e.g. Davidson, Amso, Anderson, & Diamond, 2006).

While EF has continued to gain support as a multidimensional construct (Bull, Espy, Wiebe, Sheffield, & Nelson, 2011; Davidson et al., 2006; Miyake et al., 2000; Wiebe, Espy, & Charak, 2008), there is still disagreement regarding the specific domains involved. Most researchers agree that EF domains involve processes that facilitate goal-oriented behaviors, such as inhibition, working memory, planning, and flexibility (Anderson, 2002; Bull et al., 2011; Denckla & Reiss, 1997; Espy, 2004; Pennington, 1997; Valeri, 2011; Welsh et al., 1991; Wiebe et al., 2008; Zelazo, Carter, Reznick, & Frye, 1997b). Other models have contended that EF encompasses not only cognitive
processes but also behavioral and emotional processes, such as motor control (Barkley, 1997), emotional control (Gioia, Isquith, Guy, & Kenworthy, 2000), and vigilance (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). In general, EF is depicted as a hierarchical systematic structure of independent, yet integrated, goal-oriented functions expressed in terms of behavior, emotion, and cognitive processes.

**Methodology for Assessing Executive Functioning in Preschool**

The assessment of EF in young children is challenging. In general, the measurement of EF is an attempt at capturing the complex, higher-order processes subsumed within the EF construct (Gioia, Espy, & Isquith, 2003). Many performance-based EF measures tap narrow, domain-specific components of EF (Isquith, Crawford, Espy, & Gioia, 2005). For instance, the Shape School (Espy, 1997), which was developed for use with preschool populations, measures EF domains of inhibition, shifting, and working memory. In addition, the majority of performance-based measures for children, such as the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001), are comprised of domain-specific EF tasks that are adapted from adult-based assessments (Anderson, 2002; Isquith et al., 2005; Welsh et al., 1991). However, performance-based measures that have extrapolated adult-oriented tasks for the use of assessing EF in children have proven to be insensitive to the developmental changes occurring in early childhood (Carlson, 2005; Espy et al., 2001; Garon, Smith, & Bryson, 2013; Isquith et al., 2005; Welsh et al., 1991). For example, factors such as language, visual-spatial, motor, and memory skills, which are still improving during the preschool period, have been shown to mediate performance on EF tasks (Wiebe et al., 2011; Garon, Bryson, & Smith, 2008). There is also not a clear consensus on the extent to which
intelligence correlates with performance on EF tasks during the preschool period (Ardila, Pineda, & Rosselli, 2000; Mahone et al., 2002; Welsh et al., 1991), which is likely due to similar confounding factors. In general, there are individual differences that occur within typical development of EF related to “age of onset, the rate of development, the level of proficiency at any given age, and the shape of the trajectory of skill acquisition” (Gioia et al., 2003). Overall, methodological practices for assessing EF abilities in preschoolers need to take into account the advances in neurodevelopmental maturation that coincide with skill attainment in preschool.

In addition to considering developmental changes when choosing an EF measure, it is also important to consider how EF deficits impact everyday functioning. Research has shown that EF deficits play a part in mediating the behavioral, social, and emotional outcomes of children (Anderson, 2002; Diamond & Lee, 2011; Espy et al., 2011; Marlowe, 2000). Performance-based measures tend to have high internal validity, due to the methodological constraints and standardized administration of novel, one-on-one tasks; however, it is unclear how the EF deficits elicited from these highly controlled situations translate to real-world impairments (P. Anderson, 2002; Chaytor, Schmitter-Edgecombe, & Burr, 2006; Isquith et al., 2005). In the hopes of expanding the ecological validity of EF measurement tools, behavioral rating scales have been developed to capture EF behaviors seen in home and school settings (P. Anderson, 2002; Gioia et al., 2003, 2000; Isquith et al., 2005). For example, the Behavioral Rating Inventory of Executive Functioning Preschool Version (BRIEF-P; Gioia, Espy, & Isquith, 2003) is used to measure EF domains including inhibition, shifting, emotional control, working memory, and planning and organization through parent report. The individual domains
measured are converted into higher order domains including self-control, flexibility, and metacognition. Some researchers have found that the BRIEF shows poor reliability in comparison to performance based measures. In particular, Vriezen and Pigott (2002) examined EF patterns in a sample of children with traumatic brain injury (TBI) and found differences between parent reports of EF skills on the BRIEF and the child’s performance on EF tasks. However, researchers suggested that the poor reliability between the parent report of EF impairment as seen in behavior and the child’s performance on EF tasks is likely due to the poor ecological validity of performance based measures, related to certain measures developed from adult-based tasks, which are often insensitive to EF domains in childhood populations (Vriezen & Pigott, 2002). Similarly, the BRIEF has been shown to be sensitive to parent and teacher ratings of behavioral and attention problems in children (McAuley, Chen, Goos, Schachar, & Crosbie, 2010), but these findings were suggested to support the theory that the BRIEF captures EF impairments related to behavioral regulation difficulties, which is more likely to be seen in children with socioemotional problems. Although the direction of the relationship between EF impairments and behavioral problems is not well understood, the BRIEF parent report has been shown to be sensitive to disruptions in behavioral and emotional functioning in school age children. Behavioral rating forms such as the BRIEF-P offer a comprehensive EF assessment by capturing a wide array of EF components (behavioral, social, emotional) observed in broader contexts than the laboratory setting (P. Anderson, 2002; Isquith et al., 2005).

In summary, EF is commonly measured through use of performance-based measures and behavioral rating forms. While both methods afford certain strengths, they
also possess limitations important for understanding EF in childhood, including consideration of age-related changes and generalizability to multiple contexts. The relationship between performance-based measures and behavioral ratings forms is also poorly understood (Isquith et al., 2005; Mahone & Hoffman, 2007; Toplak, Bucciarelli, Jain, & Tannock, 2009; Toplak, West, & Stanovich, 2013). While no gold standard exists for measuring EF deficits in young children, developmentally sensitive measures of EF in young children may facilitate a better understanding of the formation of EF in childhood and provide greater insight into the problems associated with EF deficits.

Development of EF

The development of EF is not well understood, but it is assumed to be a prolonged process (Gioia et al., 2003). In particular, one study attempted to outline normal EF development in participants ranging from three to 28 years of age (Welsh et al., 1991). It is established that EF skills coincide with the developmental trajectory of the prefrontal cortex (PFC; Best & Miller, 2010; Espy, 2004; Welsh et al., 1991), which is continually developing in childhood and is not fully formed until early adulthood (Espy, 2004; Stuss, 1992; Welsh et al., 1991; Wiebe et al., 2008). In infancy, children begin to hone their skills related to attentional control, self-regulation, and problem-solving. As children grow and develop, they become more skilled at enacting goal-oriented actions and prosocial behaviors (Anderson, 2002; Bull, Espy, & Wiebe, 2008; Espy et al., 2011).

The developmental trajectory for EF is not always a steady one, with surges of improvement in EF noted between the ages of three and four, five and six, and nine and ten (Welsh et al., 1991). It has also been shown that EF domains develop at an uneven rate, with individual domains developing at a quicker pace than others (Garon et al.,
2013; Welsh et al., 1991). Specifically, some EF domains, such as inhibition, peak or stabilize early (i.e., 10 to 12 years of age), with the inhibitory abilities in early adolescence comparable to skills seen in adulthood (Welsh et al., 1991). Other EF domains, such as working memory, evidence a more prolonged rate of maturation and appear to stabilize in late adolescence and early adulthood (Welsh et al., 1991). In contrast to EF domains that are observable in infancy, some EF skills that are associated with more complex processing abilities, such as planning and organization, are not observed until the preschool period (P. Anderson, 2002; Welsh et al., 1991). Not surprisingly, these EF abilities that require higher-order cognitive proficiency for goal-formation, such as planning and organization, are among the last to mature (Gioia et al., 2003).

Early childhood, in particular, is a critical period in EF development. Research has shown that EF domains experience significant growth during this period, with EF skills becoming more automatic and adaptive (P. Anderson, 2002; Welsh et al., 1991; Wiebe et al., 2011). Anderson (2002) reported significant changes occurring in EF domains of attentional control between birth and age five. Domains involving information processing, cognitive flexibility, and goal setting develop appear to develop closer to age two and steady around age seven. In addition, Carlson (2005) found that children between ages two and six demonstrated a significant improvement in performance on a number of EF tasks tapping areas of inhibition and working memory. These rapid changes seen in EF during early childhood set the groundwork for developing higher order cognitive processes (Best & Miller, 2010; Carlson, 2003; Garon et al., 2008). With EF skill advancement comes improvement in one’s regulatory
abilities, such as the adaptation of emotional and behavioral responses based on encounters with new environmental demands like schooling (Espy et al., 2011). Many of the areas of EF growth seen in the preschool period, such as inhibition (Macdonald, Beauchamp, Crigan, & Anderson, 2013; Wiebe et al., 2011), attention (Anderson, 2002; Zelazo et al., 1997), and effortful control (Liew, 2012; Zhou, Chen, & Main, 2012), are associated with increased school readiness and academic success (Best, Miller, & Jones, 2009; Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Blair, 2002). Similarly, research has shown that EF deficits negatively impact children’s ability to interact with their environment resulting in impaired cognitive and behavioral functioning (Anderson et al., 2010; De Luca et al., 2003). In particular, research has shown that damage to specific brain regions implicated in atypical EF development, such as the prefrontal cortex, are associated with impulsivity, poor self-control, and other behavioral problems (Blair & Diamond, 2008; Pennington, 1997; Stuss, 1992; Valeri, 2011; Welsh et al., 1991). Overall, EF deficits have been shown to negatively impact social and emotional functioning (Anderson, 2002; Pennington & Ozonoff, 1996; Stuss, 1992).

**EF and Developmental Disorders**

In addition to individual differences that emerge within typical EF development based on age and skill attainment, children with developmental disorders have been shown to follow unique EF developmental trajectories (Barkley, 1997; Bull et al., 2008; Espy et al., 2011; Gioia, Isquith, Kenworthy, & Barton, 2002). For example, some researchers suggest that attention-deficit/hyperactivity disorder (ADHD) arises primarily from deficits in inhibition and then manifests in secondary areas related to poor motor control and lack of emotional regulation (Barkley, 1997; Nigg, 2001). Severe and
profound EF deficits have also been observed in children with autism spectrum disorder (ASD; Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Geurts, Corbett, & Solomon, 2009; Goldberg et al., 2005; Ozonoff & McEvoy, 1994) specifically in domains of inhibition, flexibility, shifting, and working memory (Corbett et al., 2009; Ozonoff & Jensen, 1999; Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009; Verte, Geurts, Roeyers, Oosterlaan, & Sergeant, 2006). In addition, children with specific language impairment (SLI) have evidenced EF impairments in areas of inhibition, attention/processing, and working memory (Henry, Messer, & Nash, 2012; Im-Bolter, Johnson, & Pascual-Leone, 2006; Marton, 2008).

Given the consistent overlap in domains of EF deficit among developmental disorders, discrimination between disorders are often hard to make. Nonetheless, researchers argue that there appear to be distinct pattern differences across domains of EF that are specific to disorders (Gioia et al., 2003). It has been suggested that developmental disorders may possess “executive fingerprints,” such that the presentation of patterns of EF deficit may be used to discriminate among developmental disorders and differentiate groups from typically functioning peers (Ozonoff & Jensen, 1999).

Although little research has been done on profiles among preschoolers, studies have examined profiles within school age population. Gioia, Isquith, Kenworthy, and Barton (2002) determined that school age children with developmental disorders demonstrated unique profiles of EF on the BRIEF parent report in comparison to a control group of typically functioning peers (Gioia et al., 2000). Their sample included school age children with developmental disorders, including ADHD (inattentive & combined subtype), ASD, and other disorders, such as reading disorder, and traumatic
brain injury (TBI), and a comparison group of typically developing peers. Findings revealed a significant interaction between BRIEF subscale and diagnosis, such that the patterns of elevation across BRIEF scales, with higher scores indicating increased impairment, were shown to vary among diagnostic groups (Gioia et al., 2002).

Specifically, school aged children with ADHD (including both subtypes) had more problems related to inhibition (INH), working memory (WM), planning and organization (PO), and monitoring performance and behavior compared to same age counterparts with reading disorders and typical development. Subtype differences also emerged, with school-aged children with ADHD-combined subtype showing significantly greater elevations on INH compared to children with ADHD-inattentive subtype. In addition, children with ASD showed significantly more impairment on all BRIEF scales, but they showed distinctly greater problems related to inflexibility (SHFT) compared to all other groups. Children with reading disorders were rated similarly to children with ADHD-inattentive subtype, with differences noted in terms of mean level of severity as compared to the ADHD-inattentive group. Children with moderate TBI demonstrated similar patterns of scale elevation as the control group of typically functioning peers. In contrast, the severe TBI group showed higher elevations on BRIEF subscales of impairment related to INH, SHFT, WM, and PO compared to the control group, but did not surpass other groups in terms of scale elevation. Overall, children with ADHD (both subtypes) and ASD demonstrated significantly higher elevations, and thus significantly more impairment, across all BRIEF subscales compared to all other groups, but showed distinct patterns of elevation between INH and SHFT subscales.
Given the differences observed in EF patterns in elementary school children, it would be reasonable to suggest that unique patterns of EF deficits may emerge among preschool children with developmental disorders as well (Espy, Kaufmann, McDiarmid, & Glisky, 1999; Isquith, Gioia, & Espy, 2004). In order to expand upon the success of the BRIEF, which captured EF deficits in school age children, the measure was modified for use in preschool populations (BRIEF-P; Gioia et al., 2003; Isquith et al., 2005, 2004). The BRIEF-P has been shown to differentiate typical from atypical preschoolers. Specifically, Isquith, Gioia, and Espy (2004) found that preschool children with developmental disorders including ADHD, ASD, and language disorders had EF profiles on the BRIEF-P that were significantly different from EF profiles of children with typical development. Specifically, findings showed that preschoolers with developmental disorders demonstrated greater impairment across all EF domains of the BRIEF-P (Isquith et al., 2004). However, no comparisons were made among diagnostic groups.

In order to expand upon previous research, Hlavaty, Short, Gross, Cooper, and Noeder (2015) assessed whether specific patterns of EF deficits (measured on the BRIEF-P) would emerge based on diagnosis in a sample of preschool children with ADHD, ASD, SLI, and typical development. Multivariate profile analysis, using repeated measures analysis of variance (ANOVA), examined diagnostic group means across BRIEF-P subscales to determine the presence of pattern differences. Findings revealed a significant interaction between BRIEF-P subscales and diagnosis, such that distinct patterns emerged based on diagnosis (Hlavaty, Short, Gross, Cooper, & Noeder, 2015). Specifically, children with ADHD demonstrated elevations on INH that were significantly greater than the SLI and typical group and elevations on WM, and PO that
were significantly greater than the typical group. Children with ASD demonstrated elevations on INH and EC that were statistically greater than the SLI and typical groups and elevations on SHFT, WM, and PO that were significantly greater than the typical group. Children with SLI demonstrated a pattern that was similar to children with ADHD but had significantly lower scores than the ADHD group on INH. The SLI group also showed significantly more impairment on WM compared to controls. Children with typical development demonstrated consistent and normative development across all five EF skills. Overall, the EF profiles among the diagnostic groups were quite different, and children with ADHD and ASD showed the highest level of impairment across all BRIEF-P subscales, with a few exceptions related to INH and SHFT. Children with ADHD showed the highest elevations on INH, but scores were not statistically different from ASD. Children with ASD showed the highest elevation on SHFT but were only statistically different from the typical group.

**Current Study**

Despite the prevalence of research demonstrating the existence of EF deficits in children with developmental disorders, the differential pattern of EF impairment coinciding with the specific diagnosis is not well understood. This study will expand upon information gathered from multivariate profile analyses (Hlavaty et al., 2015) and examine patterns of EF in preschool children using hierarchical cluster analysis techniques (HCA). Multivariate approaches to profile analysis are limited due to the heavy reliance on within-group mean values to illustrate between group differences and subtest score patterns (Tabachnick & Fidell, 2012). In contrast, HCA algorithms can be used to allow the data to group into homogenous, natural groupings without limits being
placed on the number of groups expected. Cluster analytic methods have been used to

group children with developmental disorders. In particular, Speece, McKinney, and

Appelbaum (1985) used hierarchical cluster analysis to classify children with learning
disorders into homogenous clusters. Findings showed that different patterns of

maladaptive learning and behavior problems emerged within a population of children

with learning disorders (Speece, McKinney, & Appelbaum, 1985). Similarly, cluster

analysis has been applied to disorders that represent a spectrum of problems, such as

autism spectrum disorders, and demonstrated the presence of subtypes of children with

varying levels of social, emotional, and behavior problems (Eaves, Ho, & Eaves, 1994).

Methods of HCA have been described as data driven, due to individual cases

being classified into groups based on both their shared similarity with other cases in the

same group and also their shared dissimilarity from other groups (Aldenderfer &

Blashfield, 1984; Kaufman & Rousseeuw, 1989). This person-centered approach to

classification allows one to study individuals on the basis of their “individual

characteristics that are relevant for the problem under consideration” (Bergman &

Magnusson, 1997). Thus, cluster analysis techniques can provide additional information

for exploring patterns within groups and allows clusters of homogeneous groups to

emerge independent of diagnostic grouping. In addition, person-centered classification

systems can help identify patterns of behavior and distinguish groups who may need

more targeted intervention.

The first objective of this study was to determine if clusters of homogeneous EF

profiles emerged in a sample composed of preschool children who exhibited symptoms of

ADHD, ASD, SLI, or typical development. It is hypothesized that clusters generated
from HCA will demonstrate profiles containing predominantly EF deficits in cognitive areas (working memory and planning and organization), a profile demonstrating a combination of behavioral and cognitive EF deficits (inhibition, working memory, and planning and organization), profiles of elevation globally across behavior and cognitive EF deficits, and a profile demonstrating normative patterns of EF across all BRIEF-P subscales.

The second objective of this study was to compare the HCA classification results with the previously generated mean-based profiles to determine the extent to which the two procedures provide convergent results. The results of the current study will be used as a method of exploring whether the mean based patterns identified in previous research can be replicated statistically. In general, the rationale for identifying distinct profiles within the whole sample independent of actual diagnostic category was hypothesized to be useful since it has the potential to provide useful information about shared behavioral characteristics, rather than permitting the use of generalized statements about individuals based on their diagnostic group membership. For instance, given the heterogeneity within developmental disorders, membership to a certain diagnostic group does not always allow practitioners to infer the same predictive information for social, emotional, and treatment outcomes. Although profile results obtained from the multivariate approach versus the cluster analysis approach are not expected to be identical, the theoretical relevance of the profiles garnered from both methods is expected to be somewhat compatible. It is hypothesized that clusters will be formed that consist predominantly of certain diagnostic groups, such as ADHD or ASD, however, clusters are also expected to contain diagnostic overlap based on groups that have similar patterns of EF deficits, such as a cluster
containing both children with ADHD and SLI who demonstrate similar patterns of EF deficit in cognitive domains (working memory, planning and organization). In addition, it is hypothesized that a group of predominantly typically functioning children will form based on their profiles of consistently low impairment seen in multivariate profiles.

The third objective of this study is to describe HCA results in regards to parent ratings on symptom inventories assessing behavioral, emotional, and language functioning. It is hypothesized that clusters composition will likely drive differences on corresponding parent report measures, however, it is expected that patterns of EF strength and weakness will also influence outcomes across domains of behavioral, emotional, and language functioning. For example, clusters of children who demonstrate consistently low or normative levels of EF impairment across all domains are expected to show similarly low levels of impairment in parent rating of behavioral and emotional problems, but show possible problem areas within parent ratings of language functioning. Clusters with normative EF levels are also hypothesized to show fewer areas of parent reported problems in comparison to clusters that have higher levels of EF impairment in behavioral, emotional, and cognitive domains. Similarly, clusters that show impairment in EF cognitive domains (WM, PO) are expected to be associated with impairment in both behavioral and language functioning, but show not as many difficulties in emotional domains. Clusters with only EF cognitive impairments are expected to have more areas of difficulty in comparison to clusters with normative function, but demonstrate lower levels of impairment in comparison to clusters that demonstrate EF impairment in behavioral domains and clusters that have more severe, global EF impairments. Clusters that demonstrate greater levels of impairment across EF behavioral domains (INH, SHFT,
EC) are expected to demonstrate higher levels of behavioral and emotional problems on parent report measures in comparison to clusters that have normative EF or EF impairment in cognitive areas only. However, it is hypothesized that clusters with only EF impairment in behavioral domains will show fewer problems in comparison to clusters with more global EF impairments across behavioral, emotional, and cognitive domains. Lastly, clusters of children who show consistently high levels of impairment across all domains of EF are hypothesized to demonstrate similarly high patterns of elevation across all parent ratings and demonstrate the most severe levels of global impairment related to parent reported behavioral, emotional, and language problems.

The results of this study can help determine whether unique patterns of EF deficits exist within a population of preschool children with typical and atypical development. In comparing the two approaches (multivariate mean comparison versus cluster analysis) to classifying EF profiles, the results may help provide information to researchers and practitioners on the characteristics of students within diagnostic groups as well as within homogeneous clusters of EF profiles. With cluster analysis, it is important to note that group assignment is based on the degree of similarity with other cases and the results of these classification procedures are sample dependent (Aldenderfer & Blashfield, 1984). Therefore, HCA should be viewed as an exploratory, data driven approach for more thoroughly examining characteristics of individuals in order to improve case conceptualization. Overall, increasing our understanding of EF profiles can provide important information for improving our current classification system for preschoolers with developmental disorders and aid in the development of more efficacious early intervention programs.
Method

Participants

A sample of 107 preschool children was recruited for the purposes of a larger study examining play as an assessment tool (Short, Gorovoy, Russ, & Lewis, 2008). Three groups of preschoolers with developmental disorders were selected based on varying degrees of linguistic and behavioral problems, including specific language impairment (SLI), attention-deficit/hyperactivity disorder (ADHD), and autism spectrum disorder (ASD). Participants with developmental disorders had established diagnoses using DSM-IV criteria and were referred by managed care facilities in the Cleveland/Northeast Ohio area, including private referral sources, assessment centers, or community treatment and outreach organizations, including the Cleveland Hearing and Speech Center, University Hospitals of Cleveland, the Cleveland Clinic, Milestones, and Autism Speaks. In addition, children with typical development were recruited for the purposes of having a comparison control group. Children with typical development were recruited through flyers posted on a community board at a private University in the Cleveland area. All children included in the control group were confirmed as following typical development through information suggesting lack of previous or current diagnosis of a developmental disorder, parent paperwork indicating concerns, and parent ratings of behavioral, linguistic, and emotional problems.

Upon recruitment for the larger study, children completed a full battery of standardized assessments and parents completed parent-report forms to assess cognitive, behavioral, and language functioning. During the later stages of the larger study, the parent report forms utilized in the study was expanded to include more global ratings of
parenting stress and executive function difficulties, including the BRIEF-Preschool
Version (BRIEF-P; Gioia et al., 2003). Therefore, 22 children who were recruited during
the early stages of this study were excluded due to not receiving certain parent forms,
such as the BRIEF Preschool Version, which is essential for the purposes of this study. In
addition, there was one child that was excluded from the study due to not having any
parent forms completed. And, lastly, two children (ADHD=1, ASD=1) were excluded
from this study because they were unable to complete the assessment battery and parent
paperwork was not collected. In total, 82 children were included for analysis.

Within the group selected for inclusion, there were 57 children with
developmental disorders, including 18 children with SLI, 21 children with ADHD, and
18 children with ASD, along with a total of 25 children with typical development. The
sample of children ranged in age from four to seven years old (M=5.80, SD=0.99). The
sample was predominantly male (77%, N=63), which is not uncommon in samples of
children with developmental disorders. In order to establish group uniformity based on
gender, recruitment efforts were directed at selecting males who were typically
developing. In addition, the diversity of the sample reflected the parameters of managed
care practices in the area: 89% Caucasian (N=73), 9% African American (N=7), and 3%
Biracial (N=2).

Measures

Upon recruitment, children were required to complete a full battery of testing,
which included assessment of cognitive functioning. In addition, parents were asked to
complete a number of parent-rating forms to assess their perception of their child’s
behavioral, social, and emotional functioning across symptom reports and behavior
ratings of executive function. While the diagnostic-specific symptom inventories were used for purposes of describing the diagnostic groups in regards to areas of impairment, the BRIEF-P was used as the primary dependent variable within the data analysis.

**Demographic descriptive measures.** Data for demographics and referral concerns were obtained from the Social Medical Questionnaire (SMQ; Manos, 2004). The parent report SMQ (Manos, 2004) has been used in previous work with samples of children with ADHD (see Short, Fairchild, Findling, & Manos, 2007 for a complete description). Children’s current cognitive functioning was assessed using age-appropriate intelligence tests. Children either completed the Wechsler Primary Performance Scale of Intelligence Third or Fourth Version (WPPSI-III, WPPSI-IV; Wechsler, 2002, 2012), or the Wechsler Intelligence Scale for Children Fourth Edition (WISC-IV; Wechsler, 2003). Since assessment of cognitive functioning in preschool children in general, and children with SLI in particular (Duff, Schoenberg, Scott, & Adams, 2005; Henry et al., 2012; Wiebe et al., 2011) is adversely affected by the presence of a high verbal load on most tests, only nonverbal intelligence indices (i.e., PRI and PSI) will be used to describe the sample. Overall, the sample demonstrated average nonverbal intelligence (PRI: $M=111$, $SD=14.4$; PSI: $M=103$, $SD=15.3$), suggesting this sample is relatively high functioning compared to other samples of children with developmental disorders.

**Dependent variable of interest.** The Behavior Rating Inventory of Executive Function Preschool Version (BRIEF-P; Gioia et al., 2003) measures behavioral problems associated with EF deficits and is used as the primary variable of interest in data analysis. The BRIEF-P is a parent rating scale used to assess behavioral expression of problems related to domains of executive function (EF) in preschool children (ages 2 to 5). To
allow the same version of the BRIEF-P to be used for everyone in the study, we used the preschool version for all subjects, although some children were 5 years or older. The alternative would have been to use the BRIEF school age version (ages 6 to 18), which would have been less appropriate for the age range of our sample as a whole. Parents rate their responses based the frequency of problem behaviors occurring over the past six months using a 3-point Likert Scale (0=Never, 1=Sometimes, 2=Often) across 63 items. Items on the BRIEF-P are categorized into five domains, including Inhibit (INH), Shift (SHFT), Emotional Control (EC), Working Memory (WM), and Planning and Organization (PO). The INH scale assesses behavioral regulation in the form of inhibitory control, SHFT measures mood regulation in situations of change in routine or transition in activities, EC indicates age-appropriate emotional responses, WM reveals problems related to sustained attention and short-term memory, and PO examines behaviors related to problem-solving and task-management. Broadly, these five domains can be described as representing three behavioral domains (INH, SHFT, EC) and two cognitive domains (WM, PO). The BRIEF-P has been shown to follow a three factor solution of nonorthogonal factors (Gioia et al., 2003; Isquith et al., 2005): Inhibitory Self Control (INH+EC), Flexibility Index (SHFT+EC), Emergent Metacognition Index (WM+PO). The five clinical domains also compose into one overall composite score: Global Executive Composite (INH+SHFT+EC+WM+PO; Gioia et al., 2003). For the purposes of this study, only scores across the five major clinical domains were utilized as the primary variables for which clusters were formed within the cluster analysis.

Raw scores in each domain are converted into standardized T-scores based on age and gender. Clinical impairment is defined by T-scores that are greater than or equal to
The BRIEF-P has been shown to have high internal consistency ($\alpha= .80$ to .97) and significant test-retest reliability ($r= .86$) in clinical samples. The BRIEF-P has been validated against other widely used parent-report measures, such as the Child Behavior Checklist for 2½ to 5 year olds (CBCL 2½ - 5; Achenbach & Rescorla, 2000) and the Behavior Assessment System for Children (BASC; Reynolds & Kamphaus, 1998). In addition, the BRIEF-P has been utilized in populations of children with varying developmental disorders, such as ADHD, ASD, language disorders, and premature birth (Gioia et al., 2003).

**Outcome measures for validating clusters.** Maternal report of the participant’s current functioning was obtained through symptom inventories and behavioral rating forms. Specifically, language functioning associated with SLI was measured using the Adaptive Language Inventory (ALI; Feagans & Farran, 1979) symptoms of ADHD were measured using the Conners’ Rating Scale-Parent Version (CRS-P; Conners, Sitarenios, Parker, & Epstein, 1998)); and symptoms of ASD were measured using the Gilliam Autism Rating Scale (GARS; Gilliam, 1995). In general, a range of impairment was observed across all parent-report measures, but was indicative of a relatively high functioning, managed care sample.

**Adaptive language inventory (ALI; Feagans & Farran, 1979).** The ALI (Feagans & Farran, 1979) is an 18 item parent report measure used to assess language ability in children. Item responses are rated on a 5-point Likert scale ranging from 1 (below average) to 5 (above average). Items are categorized into 6 major domains, including Comprehension, Production, Rephrase, Spontaneity, Listening, and Fluency, and mean scores for each domain are used to assess language ability. The Comprehension
subscale assesses a child’s ability to understand directions and stories. The Production subscale measures the child’s ability to verbally answer questions or provide detailed information. The Rephrase subscale reveals a child’s ability to retell or paraphrase second hand information. The Spontaneity subscale indicates the child’s ease and timing of verbal interaction. The Listening subscale assesses the child’s ability to sustain attention and reiterate information. The Fluency subscale measures the child’s articulation abilities. All of these subscales compose a Total Language composite score, which can be used to assess overall language functioning.

**Conners’ rating scale- Parent version (CRS-P; Conners et al., 1998).** The CRS-P is a parent report measure used to assess attentional and behavioral problems typically seen in children ages 6 to 18. Parents choose responses based on the frequency of observed problem behavior over the past month using a 4-point Likert scale, ranging from 0 (not at all) to 3 (very much). Six subscales are included on the CRS-P, including Conduct Problems, Learning Problems, Psychosomatic problems, Impulsivity-Hyperactivity, Anxiety, and a Hyperactivity Index. Raw scores are converted into standardized T-scores based on age and gender, with scores between 60 to 69 considered borderline range and scores 70 and above in the clinical range.

**Gilliam Autism rating scale (GARS; Gilliam, 1995).** The GARS (Gilliam, 1995) is a parent report measure used to assess frequency of behaviors commonly seen in children with ASD. Parents indicate item frequency using a 5-point Likert scale ranging from 0 (never) to 4 (frequently). Items are categorized into four major subscales including Stereotyped Behaviors, Communication, Social Interaction, Developmental Disturbances, and one overall composite score, Autism Quotient. The Stereotyped
Behaviors, Communication, and Social Interaction subscales are intended to capture current patterns of atypical behavior and the Developmental Disturbances subscale assesses atypical behavior in the child’s history. The Autism Quotient is to be used to examine the overall likelihood of a child exhibiting autistic symptoms. Raw scores are converted into standardized scores, which are then used to describe individual subscales ($M=10$, $SD=3$) and the composite score ($M=100$, $SD=15$).

**Procedure**

A hierarchical cluster analysis (HCA) was conducted using SPSS in order to generate hypotheses about the number of clusters within the data. The procedure for hierarchical agglomerative clustering involves each case starting out as its own cluster and then following a series of partitions within the data to eventually create one large cluster containing all cases. Individual cases within the data are paired together based on selection of agglomerative methods that use either patterns of similarity or difference as pairing criterion. Within this study, Ward’s method of agglomeration (Ward, 1963) was employed due to its ability to reduce within group variance and to produce clusters of relatively equal sizes (Aldenderfer & Blashfield, 1984; Everitt, Landau, Leese, & Stahl, 2011). Ward’s method pairs cases together in clusters while accounting for the error sum of squares criterion, which is aimed to minimize the total within-cluster error sum of squares of final clusters (Ward, 1963). Studies have shown that Ward’s linkage procedures tend to produce more homogeneous clusters in comparison to other agglomerative methods (Blashfield, 1976; Everitt et al., 2011). In addition, Squared Euclidean distance was chosen as the proximity measure for formulating clusters. Squared Euclidean distance measure takes into account dissimilarity between individual
cases to formulate clusters that demonstrate similar magnitudes (Aldenderfer & Blashfield, 1984). The five non-overlapping clinical scales on the BRIEF-P, including INH, EC, SHFT, WM, and PO were standardized and included as the variables of interest in the HCA. The three indices and global composite scale of the BRIEF-P were excluded from analysis due to the aggregated nature of their composure from the five clinical scales.

Due to the exploratory nature of cluster analytic techniques, it is important to note that even random data will produce some form of clustered results. Therefore, supplemental analyses are recommended for providing descriptions of internal and external validity of clusters (Aldenderfer & Blashfield, 1984; Everitt et al., 2011). In order to supplement clinical and theoretical considerations toward cluster interpretation, multiple mathematical techniques were used to validate the number of clusters retained for final discussion. First, the dendogram from the HCA was examined to determine the number of potential clusters available. The Variance Ratio Criterion (VRC; Caliński & Harabasz, 1974) technique was used to help determine the number of clusters to retain. The VRC method involves computing a pseudo F statistic across possible cluster solutions in order to find the “best” number of clusters within the data. The VRC method is computed by taking the overall between-subjects sum of squares divided by the overall within-subjects sum of squares across all possible clustering solutions. For solutions with \( n \) cases in \( k \) clusters, the following depicts VRC:

\[
VRC = \frac{(SS_{between}/ k-1)}{(SS_{within}/ n-k)}
\]

Within SPSS, VRC can be computed using the between sum of squares and within sum of squares values produced from one-way ANOVA results using cluster membership as
the independent variable and the clustering variables as the dependent variables. The resulting between sum of squares values and within sum of squares values are summed in association with their respective cluster solution (i.e., if ANOVA was run using 5 cluster solution IV, the between and within sum of squares values would be summed, and if a separate ANOVA using 4 cluster solution IV was run, then those between and within sum of squares values would be summed, etc.) and can then be compared across a range of cluster solutions. The results of the VRC calculation are examined to determine where separation between clusters is maximized and variance within individual cluster solutions is minimized. The VRC criterion indicates that results should be examined for a peak in values, indicating cluster solutions should be graphed and the number of clusters indicated prior to a decrease in VRC is associated with the number of cluster solutions to be retained. The VRC technique is permissible for use within either hierarchical or nonhierarchical clustering methods and has been shown to perform well at identifying known groups within clustering methods (Milligan & Cooper, 1985). Therefore, the VRC was used as a method for reducing the number of cluster solutions retained for more thorough examination. Cluster solutions were more thoroughly examined by plotting individual clusters within separate solutions and inspecting general cohesiveness of generated groups.

One limitation of hierarchical clustering is that once a case is assigned to a specific cluster, it cannot be reassigned, meaning there is no plasticity of within cluster formation. In order to address these limitations, the results of the HCA were optimized using K-means cluster analyses. K-means cluster analysis is different from HCA in that it is a partitioning method that prompts for the initial number of clusters and iteratively
clusters data around cluster centroids until a minimized sum of squares within each cluster is achieved. The process of using K-means for optimization involves aggregating the centroids of the clusters found in the HCA cluster solutions for their use as the initial centroid for the K-means cluster analysis. The results of the K-means analysis were compared to the results of the HCA to determine if clustered functioned better when the distance from the cluster means was minimized.

Because different clustering methods can produce contrasting results within the same data (Aldenderfer & Blashfield, 1984; Milligan & Cooper, 1987), a smaller subsample of the data was selected at random in order to examine cluster replication. Due to the small size of the overall sample (N=82) and the presence of multiple diagnostic groupings, a random selection of 75% of participants within each diagnostic grouping were selected for this procedure, which included 14 participants from the SLI group, 17 participants from the ADHD group, 12 from the ASD group, and 19 from the typical group. Within the randomized sample, HCA was conducted and directed to produce clusters ranging from 3 to 5 solutions, so that the cluster classifications of the randomized sample could be compared to the cluster groupings found within the overall sample. In addition to describing the percentages of cases correctly classified, Kappa coefficients were used to describe the level of agreed cluster classification within the randomized sample. Within the context of this study, Landis and Koch’s Kappa descriptors (1977) were used, with higher levels of agreement indicating higher correspondence between the cluster membership categorizations in the randomized sample as compared to the initial cluster membership in the overall sample.
**External validity.** Following internal validation techniques, cluster results were then described in regards to their general makeup of participants from different diagnostic groups. Cluster profiles were also described in relation to their similarity and difference from previously established EF profiles produced from a multivariate mean-based statistical approach (Hlavaty et al., 2015). In addition, in order to expand upon the external validity of the generated clusters, clusters were evaluated using supplemental parent report measures that were not included in the clustering methods (Aldenderfer & Blashfield, 1984). Specifically, clusters were examined for potential differences across the CRS-P, the GARS, the ALI, and demographic variables, such as age, using one-way ANOVAs.

**Results**

**Assumptions**

Prior to running the hierarchical cluster analysis (HCA), the data of interest was examined to determine the presence of multicollinearity and singularity within diagnostic groups and dependent variable subscales. Bivariate correlations were conducted to examine the relationships between dependent variables of interest (BRIEF-P Subscales). The correlation coefficients ranged from .42 to .76 and all were statistically significant.

Because both Ward’s method and Euclidean distance have been shown to be overly sensitive to elevation, which can affect generated clusters, several precautions were taken to avoid potential errors. The data was examined for univariate and multivariate outliers both in the overall sample and within diagnostic group. In addition, normality and independence of sampling was examining within the context of skew and kurtosis values both overall and within groups. No outliers or violations of normality
were detected. In examining our data set, there are no significant univariate or multivariate outliers, as judged by z-score criteria (-3.29 ≤ z-score ≤ 3.29; Tabachnick & Fidell, 2012) and Mahalanobis Distance, therefore, these methods are likely to function appropriately. Although the BRIEF-P subscales are normed and standardized into t-scores, there are slight differences across scales related to range of possible t-scores. Because distance measures, such as Euclidean distance, have been shown to be sensitive to differences in variable scale or magnitude, standardizing variables is often recommended to address these potential issues (Aldenderfer & Blashfield, 1984; Everitt et al., 2011). Therefore, the BRIEF-P subscale t-scores were standardized into z-scores across BRIEF-P subscales by the total sample within the HCA.

**Number of Clusters**

In examining the dendogram resulting from the HCA, it appeared that a range of 3 to 7 cluster solutions demonstrated the closest distance and, therefore, these possible solutions of clusters were examined more closely to determine the number of clusters to retain. In order to assess whether nested clusters should be divided, clusters were plotted around the mean of their respective cluster. The variance ratio criterion (VRC; Caliński & Harabasz, 1974) was also used to help determine the number of clusters to retain. In order to examine VRC for the range of 3 to 7 clusters, a second HCA was performed and specified to produce a range of 3 to 7 cluster solutions, which creates variables aligning with cluster membership within the SPSS database. Then, supplemental one-way ANOVAs were conducted with the cluster solutions ranging from 3 to 7 so that the between and within sum of squares for the respective solutions was obtained. The between and within sum of squares values were summed across BRIEF-P subscales
within potential cluster solutions and then divided by the degrees of freedom values to form the pseudo F-statistic for the purpose of selecting an optimal number of clusters to retain. The results of the VRC method indicated that a 3-cluster solution should be retained. In order to supplement the VRC results, individual scores were plotted around their respective means across cluster solutions, to determine which solutions produced the most cohesive plots and which were potential solutions. It was determined that cluster solutions containing 4 and 5 groupings should also be further examined due to the relative similarity in cluster composure, with two clusters remaining the same across the 3-, 4-, and 5-cluster solutions.

The stability of cluster solutions was also examined as a method for determining the number of clusters to retain. Cluster stability was examined by selecting a smaller subsample of the data at random for comparison. After randomization, it was found that 92% of the participants were correctly classified in a 3-cluster solution, 87% were correctly classified in a 4-cluster solution and 76% were correctly classified in a 5-cluster solution. Thus, the replication of the 3-cluster solution was most consistent with the original solution. Cohen's κ was run to determine if there was agreement between the initial cluster solutions within the full sample (N=82) in comparison to the randomized subsample (N=62). It was found that for the 3-cluster solution, there was almost perfect agreement between the two separate HCA procedures, κ = .86, p < .001. For the 4-cluster solution, there was also almost perfect agreement between the two separate HCA procedures, κ = .82, p < .001. Lastly, it was found that for the 5-cluster solution, there was substantial agreement between the two separate HCA procedures, κ = .75, p < .001.
Next, a K-means analysis was conducted to optimize results of the HCA to determine if there were cases within clusters that functioned better within another cluster by minimizing the distance from the cluster mean and also to examine the internal consistency of clusters by comparing the results of iteration to the initial centroids input from the HCA. The centroids from the HCA solution were first aggregated from the initial data for each cluster solution that was to be examined with K-means. Then, these initial seed values were input into K-means analysis using Euclidean Distance and specified to iterate and classify 3, 4, and 5 cluster solutions. These solutions were selected due to our interest in gaining more data on which of these two solutions was most appropriate for describing our data. K-means results revealed that within the 3-cluster solution, 11 participants were shifted to other groups to reduce the distance from cases and the center of the clusters to an average of 18.94. The 3-cluster solution revealed clusters of low, moderate, and high impairment on EF subscales. For the 4-cluster solution, a total of 4 iterations resulted in 8 participants being moved into different clusters to achieve a minimum distance of 16.91 between cases and their cluster centers. The clusters within the 4-cluster solution revealed a low, moderate, and high impairment group, but also a group that demonstrated moderate and high levels of impairment across differing EF domains. Lastly, the K-means results for the 5-cluster solution demonstrated 4 iterations resulting in 11 participants being moved into different clusters and one cluster being reduced to 7 participants. Case distance from their cluster center was on average 15.77 and revealed clusters of low and high EF impairment, two clusters of cases with moderate impairment, and one cluster of cases demonstrating a mix of moderate and high impairment across EF domains.
In addition to these steps, the cluster profiles were examined for interpretability from a psychological standpoint. In particular, clusters were examined with regard to the patterns of impairment demonstrated across clusters and the general cohesiveness of cases within clusters. Although the VRC results suggested using the 3-cluster solution, further examination revealed that this solution limited results to differences in EF impairment in regards to severity and not in regards to specific profiles across domains. In examining the 4-cluster solution, individual clusters appeared to have predominant diagnostic groupings and demonstrate relatively even groupings. The 4-cluster solution also appeared to demonstrate differences across the areas of EF strength and weakness across the clusters. In comparison, the 5-cluster solution, was formed by breaking the smallest cluster within the 4 cluster solution (N=13) into two smaller subgroups (N=6, N=7) and the general pattern of BRIEF-P scores does not seem to change, with respect to one subsample demonstrating moderate impairment with slightly lowered EF impairment in cognitive domains, but still seeming to follow similar trends from the 4-cluster solution. Therefore, in addition to consulting previous steps toward validity, it was decided to maintain the two subsamples seen in the 5-cluster solution as a single group and split the 3-cluster solution into 4 clusters so that more detailed patterns could be discussed. Thus, a 4-cluster solution, optimized with the K-means analysis, was retained and further described against external validity measures.

Cluster Interpretation

In examining individual clusters within the 4-cluster solution, BRIEF-P profiles for each cluster solution were graphed in order to better understand patterns of EF strengths and weaknesses. As shown in Figure 1, Cluster 1 presented with all BRIEF-P
scores within normal limits and demonstrated the lowest level of overall impairment. Cluster 1 (N=20) was comprised largely of children from the typical group (N=15, 75%), with 10% of the profile deriving from the SLI group (N=2), 10% of the profile deriving from the ASD sample (N=2), and 5% of the profile deriving from the ADHD sample (N=1). Cluster 2 characterized by patterns of EF behavioral domains within the normative level, with mild INH, SHFT, and EC scores, and deficits in areas of cognitive EF domains of WM and PO. Cluster 2 (N=27) was composed largely of children from the SLI group (N=11; 41%), with 26% of the profile deriving from the typical sample (N=7), 18% deriving from the ADHD sample (N=5), and 15% deriving from the ASD sample (N=4). Cluster 3 was characterized by elevations in INH, WM, and PO. Cluster 3 (N=26) was composed of largely of children from the ADHD group (N=12, 46%), with 27% of the profile deriving from the ASD sample (N=7), 15% of the profile deriving from the SLI sample (N=4), and 12% of the profile deriving from the typical sample (N=3). Lastly, Cluster 4 was characterized by global impairments in both the cognitive and behavioral aspects of EF, with clinically elevated symptoms across all BRIEF-P subscales in comparison to other groups. Cluster 4 (N=9) was composed largely of children with ASD (N=5; 56%), with 33% of the profile deriving from the ADHD sample (N=3), and 11% of the profile deriving from the SLI sample (N=1). Cluster 4 did not contain any participants from the typical sample.

In order to examine sample differences among our clusters, chi-square analyses were conducted. Preliminary analyses showed that there were no significant differences among clusters based on age (overall $M=5.80, SD=0.99$; $F[3,78]=0.18, p=.91$), gender ($\chi^2[3, n=82]=7.83, p=.05$, Cramer’s V=.31), or ethnicity ($\chi^2[9, n=82]=8.81, p=.46$,
Cramer’s V=.33). Overall, demographic analyses indicated no significant differences among the four clusters on the basis of age, sex, or ethnicity.

Interestingly, the profiles generated from the HCA appeared similar to that of the profiles generated from the previously run repeated measures ANOVA seen in Figure 2 (Hlavaty et al. 2015). In particular, Cluster 1 seemed to demonstrate a similar profile to that of the typical group. Cluster 2 demonstrated a profile that was similar to that seen in the SLI group. In addition, Cluster 3 demonstrated a profile that was similar to the ADHD group. And Cluster 4 followed a similar pattern to that seen of the ASD group, showing the highest elevations across all BRIEF-P subscales.

**External Validity of Clusters**

Clusters were compared using additional parent report measures of behavioral and language problems in order to examine the external validity. In particular, the clusters were compared across the ALI, CRS-P, and GARS. See Tables 1 through 3 for detailed information regarding the means and standard deviations of clusters and parent report measures.

As mentioned, it was hypothesized that clusters composition will likely drive differences on corresponding parent report measures, however, it was expected that patterns of EF strength and weakness would also influence outcomes across domains of behavioral, emotional, and language functioning. Specifically, clusters of children who demonstrated consistently low or normative levels of EF across all domains (behavioral, emotional, and cognitive) were expected to show fairly normative levels of functioning in relation to parent report measures. In addition, clusters demonstrating impairment in EF cognitive domains (WM, PO) were expected to be associated with impairment in both
behavioral and language functioning on the CRS-P and ALI. Similarly, clusters with a combination of EF impairment in behavioral and cognitive domains were expected to also demonstrate a higher level of problems across parent reports of behavioral, emotional, and language functioning, while also demonstrating a lower level of overall problems compared to clusters that have more global EF impairments. Lastly, clusters of children who showed consistently high levels of impairment across all domains of EF were expected to demonstrate the most severe impairment across all domains of functioning on the ALI, CRS-P, and GARS.

**ALI.** In order to examine whether EF impairments in behavioral and cognitive domains influenced parent rating of child language problems, a one-way between-groups MANOVA was performed to investigate cluster differences in language functioning, as measured by the ALI average scores. There was a statistically significant difference between clusters on the ALI, $F(6, 18) = 3.08; p < .001; Wilks’ Lambda = .51$; multivariate partial eta squared = .20. The results for the dependent variable were considered separately using post hoc Bonferroni comparisons with an adjusted alpha level of .007. There was a significant and large effect of cluster classification on Comprehension scores, $F(3, 77) = 14.02, p < .001$, partial eta-squared = .35; Production scores, $F(3, 77) = 7.14, p = .001$, partial eta-squared = .22; Rephrase scores, $F(3, 77) = 6.26, p = .001$, partial eta-squared = .20; Listening scores, $F(3, 77) = 6.42, p = .001$, partial eta-squared = .20; Fluency scores, $F(3, 77) = 5.19, p = .003$, partial eta-squared = .17.; and Total Language scores, $F(3, 77) = 7.86, p < .001$, partial eta-squared = .24. There were no significant differences across clusters within Spontaneity scores, $F(3, 77) = 1.51, p = .22$. 
As hypothesized, the severity of EF impairments, as suggested by the elevation and frequency of impairments across behavioral and cognitive domains, was shown to influence parent ratings of language problems. For groups that demonstrated mild to normative patterns of EF impairment, such as Cluster 1, few language problems were seen in comparison to groups who had more elevated EF deficits. Specifically, Cluster 1 demonstrated better language functioning in relation to Comprehension and Total Language compared to all other groups, higher Production than Clusters 3 and 4, higher Rephase and Listening than Cluster 4, and greater Fluency compared to Clusters 2 and 4.

Cluster 2, which demonstrated EF impairments solely in cognitive domains, was shown to have slightly more language problems than the EF normative group (Cluster 1). Specifically, Cluster 2 had lower Comprehension, Fluency, and overall Total Language compared to Cluster 1. Cluster 2 demonstrated better language functioning than clusters that had more global EF impairments (Cluster 4), such that Cluster 2 demonstrated higher Comprehension, Rephase, Listening, and Total Language than Cluster 4.

Cluster 3, which demonstrated a combination of EF deficits seen primarily in cognitive domains (WM and PO) but also in one behavioral domain (INH) was shown as having more language problems compared to clusters with mild EF deficits in all domains (Cluster 1). In particular, Cluster 3 demonstrated lower Comprehension, Production, and Total Language than Cluster 1. However, Cluster 3 demonstrated better language functioning in certain areas compared to clusters with more global EF impairment (Cluster 4). Specifically, Cluster 3 demonstrated higher Comprehension, Rephase, and Listening compared to Cluster 4.
Lastly, as hypothesized, Cluster 4, which demonstrated the greatest impairment across behavioral, emotional, and cognitive EF domains also demonstrated significantly more language problems than other groups. Specifically, Cluster 4 demonstrated more problems with Comprehension, Rephrase, and Listening than all other clusters, more problems with Production, Fluency, and Total Language than Cluster 1, and lower Total Language than Clusters 1 and 2.

**CRS-P.** In order to examine whether EF impairments in behavioral and cognitive domains influenced parent rating of child behavior problems, a one-way between-groups MANOVA was performed to investigate cluster differences in Behavioral Problems, as measured by the CRS-P T-scores. There was a statistically significant difference between clusters on CRS-P scores, \( F(6, 18) = 8.00; p < .001; \) Wilks’ Lambda = .22; *multivariate partial eta squared* = .40. Next, the results for the dependent variable were considered separately, using a Bonferroni adjusted alpha level of .008. There was a significant, and large effect of cluster classification on Conduct problems t-scores, \( F(3, 77) = 21.86, p < .001, \) *partial eta-squared* = .46; Learning Problems t-scores, \( F(3, 77) = 26.88, p < .001, \) *partial eta-squared* = .51; Impulsive Hyperactivity t-scores, \( F(3, 77) = 25.61, p < .001, \) *partial eta-squared* = .50; Anxiety t-scores, \( F(3, 77) = 7.54, p < .001, \) *partial eta-squared* = .28; and Hyperactivity Index t-scores, \( F(3, 77) = 49.82, p < .001, \) *partial eta-squared* = .66. There were no significant differences found within Psychosomatic problem t-scores, \( F(3, 77) = 1.43, p = .24. \)

As hypothesized, the severity of EF impairments, as suggested by the elevation and frequency of impairments across behavioral and cognitive domains, was shown to influence parent ratings of behavioral problems. For groups that demonstrated mild to
normative patterns of EF impairment, such as Cluster 1, few behavioral problems we seen in comparison to groups who had more elevated EF deficits. In particular, Cluster 1 showed fewer Learning Problems, Anxiety problems, and overall Hyperactivity index scores in comparison to all other clusters, and fewer Conduct and Impulsive Hyperactivity problems than Clusters 3 and 4.

Cluster 2, which demonstrated EF impairments solely in cognitive domains, was shown to have slightly more behavioral problems than the EF normative group (Cluster 1). Specifically, Cluster 2 demonstrated more Learning Problems and a higher overall Hyperactivity Index scores in comparison to Cluster 1. Cluster 2 also followed a milder pattern in comparison to clusters that also demonstrated EF impairments in behavioral domains (Clusters 3 and 4), such that Cluster 2 demonstrated fewer Conduct problems, Impulsive Hyperactive problems, and overall Hyperactivity index scores in comparison to Clusters 3 and 4, and fewer Learning problems in comparison to Cluster 4. Cluster 2 also demonstrated higher internalizing issues in comparison to clusters with more normative EF impairments, such that Cluster 2 demonstrated a higher level of Anxiety problems compared to Clusters 1.

Next, Cluster 3, which demonstrated a combination of EF deficits seen primarily in cognitive domains (WM and PO) but also in one behavioral domain (INH) was shown as having higher behavioral problems compared to clusters with mild EF deficit (Clusters 1) and clusters that solely had EF deficits in cognitive domains (Cluster 2). In particular, Cluster 3 demonstrated more Conduct problems, Impulsive Hyperactivity, and higher overall Hyperactivity Index scores compared to Clusters 1 and 2, and more Learning Problems than Cluster 1. In addition, Cluster 3 demonstrated a similar, but milder pattern
of behavioral problems as compared to clusters with greater EF impairments across all domains (Cluster 4). Specifically, Cluster 3 demonstrated fewer Conduct problems, Learning Problems, and lower overall Hyperactivity Index scores than Cluster 4. In addition, Cluster 3 demonstrated more internalizing issues than clusters with normative EF patterns, with Cluster 3 demonstrating significantly more Anxiety problems as compared to Cluster 1.

Lastly, as hypothesized, Cluster 4, which demonstrated the greatest impairment across behavioral, emotional, and cognitive EF domains also demonstrated significantly more behavioral problems than other groups. Specifically, Cluster 4 demonstrated more Conduct problems, Learning Problems, and higher overall Hyperactivity Index scores than Clusters 1, 2, and 3, and more Impulsive Hyperactivity problems than Clusters 1 and 2. Cluster 4 also demonstrated more internalizing issues than clusters with normative EF impairment, such that Cluster 4 demonstrated more Anxiety problems than Clusters 1.

**GARS.** In order to examine whether EF impairments in behavioral and cognitive domains influenced parent rating of child behavior and language problems, a one-way between-groups MANOVA was performed to investigate cluster differences in socioemotional functioning, as measured by the GARS standard scores. There was a statistically significant difference between clusters on the GARS, $F(5, 15) = 7.68; p < .001$; *Wilks’ Lambda* = .29; *multivariate partial eta squared* = .34. Next, the results for the dependent variable were considered separately, using a Bonferroni adjusted alpha level of .01. There was a significant and large effect of cluster classification on Stereotyped Behaviors standard scores, $F(3, 78) = 26.65, p < .001$, *partial eta-squared* = .51; Communication standard scores, $F(3, 78) = 19.25, p < .001$, *partial eta-squared* =
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.43; Social Interaction standard scores, $F(3, 78) = 30.34, p < .001$, partial eta-squared = .54; Developmental Disturbance scores, $F(3, 78) = 3.52, p = .02$; and Autism Quotient standard scores, $F(3, 78) = 26.94, p < .001$, partial eta-squared = .51.

As hypothesized, the severity of EF impairments, as suggested by the elevation and frequency of impairments across behavioral and cognitive domains, was shown to influence parent ratings of behavioral problems. For groups that demonstrated mild to normative patterns of EF impairment, such as Cluster 1, few socioemotional problems were seen in comparison to groups who had more elevated and global EF deficits. Specifically, Cluster 1 demonstrated fewer problems related to Communication and Social Interaction in comparison to all other clusters, fewer problems in relation to Stereotyped Behavior overall Autism Quotient scores compared to Clusters 3 and 4, and fewer Developmental Disturbances than Cluster 4.

Cluster 2, which demonstrated EF impairments solely in cognitive domains, was shown to have slightly more socioemotional problems than the EF normative group (Cluster 1). Cluster 2 demonstrated more problems with Stereotyped Behavior, Communication, and Social Interaction than Cluster 1. However, Cluster 2 demonstrated lower levels of socioemotional impairment in comparison to clusters that had EF impairment in behavioral and emotional domains. In particular, Cluster 2 demonstrated lower problems related to Stereotyped Behavior than Clusters 3 and 4, and lower Communication problems, Social Interaction problems, Developmental Disturbances, and overall Autism Quotient scores than Cluster 4.

Cluster 3, which demonstrated a combination of EF deficits seen primarily in cognitive domains (WM and PO) but also in one behavioral domain (INH) was shown as
having higher socioemotional problems compared to clusters with mild EF deficits in behavioral domains (Clusters 1 and 2) and clusters that solely had EF deficits in cognitive domains (Cluster 2). Specifically, Clusters 3 higher levels of Stereotyped Behavior and higher overall Autism Quotient scores in comparison to Clusters 1 and 2, and higher levels of Communication and Social Interaction problems than Cluster 1. Cluster 3 also demonstrated score patterns that were elevated, but milder than the socioemotional problems seen in the more global EF impaired cluster (Cluster 4). In particular, Cluster 3 had fewer problems related to Communication, Social Interaction, and lower overall Autism Quotient scores in comparison to Cluster 4.

Lastly, as hypothesized, Cluster 4, which demonstrated the greatest impairment across behavioral, emotional, and cognitive EF domains also demonstrated significantly more socioemotional problems than other groups. Specifically, Clusters 4 had more problems related to Stereotyped Behaviors, Communication, Social Interaction, and higher overall Autism Quotient scores in comparison to all other groups (Clusters 1, 2, and 3), and more problems related to Developmental Disturbances than Clusters 1 and 2.

Discussion

In the preschool period, there is a wide array of behavior problems that are within the window of typical development. For example, difficulties with attention, self-control, inhibition, language, and behavior-regulation are commonly seen in preschool children. This makes the process of differentiating between developmental disorders in preschool children inherently difficult. Rather than trying to differentiate between disorders, it may be beneficial for screenings to initially focus on differentiating between typical and atypical behaviors. Given the varying symptom presentation seen in disorders such as
ADHD and ASD that have multiple subtypes or dimensions, it is likely that patterns of EF abilities and deficits may also overlap.

Based on the results of the HCA in the current study, it is evident that EF profile differences emerge among preschool children with a variety of developmental disorders. In particular, profiles depicting patterns of behavioral and cognitive EF deficits were seen across clusters. Cluster 1, which was composed predominantly of typically functioning children, demonstrated patterns that were consistent across EF domains and within the normal level of functioning. Cluster 2, which was composed predominantly of children with SLI, demonstrated normal levels of functioning in EF behavioral domains of inhibition, shifting, and emotion control, but showed greater impairment in EF cognitive domains of working memory and planning and organization. Cluster 3, which was composed of predominantly children with ADHD, showed impairment in EF domains of inhibition, working memory, and planning and organization. Lastly, Cluster 4, which was composed of predominantly children with ADHD and ASD, showed the greatest level of impairment across all domains of EF. These findings are fairly consistent with the EF profiles seen within diagnostic groupings.

Cluster groupings were validated by comparing them to parent reports used to assess behavioral and language impairment lend credence to the value of EF measures in the preschool period. In addition, EF measures appear to be successfully capturing both cognitive and behavioral differences in the groups. Children with significant EF impairments also demonstrated significant behavioral and language impairments as compared to preschoolers with no or minimal EF impairments. Cluster 4 evidenced the highest elevations on the BRIEF-P subscales and were also rated to be significantly more
problematic on the three behavioral ratings (i.e., CRS-P, GARS, and ALI), suggesting the comorbid presence of behavioral and language impairments. Further, Clusters 2 and 3, who demonstrated EF deficits in the moderate range compared to Clusters 1 and 4, also demonstrated a similar pattern of impairment on parent ratings of behavioral and language functioning, showing less impairment than the most impaired group (Cluster 4) but more impairment than the normative group (Cluster 1). Cluster 1, who demonstrated patterns of EF that were within the normative range, showed consistently normative behavioral and language patterns, with overall lower levels of behavioral problems and higher language functioning compared to children in other cluster groupings that had higher EF impairments.

These findings suggest that identification of unique EF profiles may be possible within the preschool period, with the possibility that these unique profiles may benefit from distinct interventions for improving outcomes. However, it is important to note that methods of cluster analysis are exploratory and that the results are somewhat limited in their generalizability. The presence of distinct groups within a group of preschoolers with typical and atypical functioning emphasizes the need for researchers to examine EF profiles across disorders so that comparison studies can be conducted and conclusions can be drawn about the specificity of these EF profiles within developmental disorders. Without future validation, the results of the present study are not only sample dependent, but also cannot be used to generalize about the etiology of the developmental trajectories of children with atypical and typical functioning. Also, due to the small size of this sample, definitive conclusions cannot be made about the generalizability of these profiles to children with typical and atypical development. In addition, the dependent variable of
interest, the BRIEF-Preschool, is a parent report form and is susceptible to error. The BRIEF school age version has been shown to be related to parent ratings of childhood behavioral problems, such as the Conners’ Rating Scales (Gioia et al., 2000; Mahone et al., 2002; McAuley et al., 2010; Sullivan & Riccio, 2007; M. E. Toplak et al., 2009) and also ADHD in general, with the BRIEF showing more sensitivity to the impairments seen in ADHD (Isquith & Gioia, 2000; Mahone & Hoffman, 2007; McAuley et al., 2010; M. E. Toplak et al., 2009). Therefore, it is also important to acknowledge that behaviors associated with EF impairment as measured by the BRIEF-P may also be sensitive to the behavioral problems seen in children with developmental disorders and may not generalize to findings obtained from performance based EF measures. In addition, this study extends the areas of impairment that the BRIEF-P may be further sensitive in detecting, such as emotional and language difficulties, as it related to EF impairments. Lastly, these findings are also limited by sample size and selection and should be considered within the context of a relatively small, localized sample within the Northeast Ohio area.

It is evident that EF deficits play a part in mediating the behavioral, social, and emotional outcomes of children (Anderson, 2002; Diamond & Lee, 2011; Espy et al., 2011; Marlowe, 2000). In fact, it is suggested that delays or deficits in EF can lead to impaired adaptive learning strategies for interacting with one’s environment (Anderson, 2002; Marlow, Hennessy, Bracewell, Wolke, & others, 2007). Impairment in the ability to learn and manage information in novel situations can then, in turn, impact a child’s ability to exhibit appropriate social and cognitive skills that are needed to demonstrate school readiness (Bierman et al., 2008; Kolnik, 2010). EF deficits have also been
implicated in the attainment of behavioral and emotion regulation skills needed for the transition to school in the preschool period (Blair, 2002; Espy et al., 2011; Wiebe et al., 2011). Overall, EF deficits negatively impact a child’s ability to establish skills needed for school readiness and attainment of academic success.

It has been shown that early interventions focused on teaching more adaptive strategies, such as problem solving skills, can improve the prognosis of school readiness (National Education Goals Panel, 1995). Further, given that EF skills experience a level of malleability in early childhood, such that skills show significant level of growth between the ages of 4 and 6 (Röthlisberger, Neuenschwander, Cimeli, Michel, & Roebers, 2012; Best et al., 2009; Welsh et al., 1991), it is possible that interventions aimed to bolster EF skills during the preschool period would allow for improvement in children with EF deficits. Interventions targeting EF deficits have shown to be effective for children with varying developmental disorders (Barenberg, Berse, & Dutke, 2011; Bierman et al., 2008; Diamond & Lee, 2011; Röthlisberger et al., 2012). However, few interventions have targeted children with EF deficits in atypical preschool populations, such as preschool children with developmental disorders. Interventions designed for these populations have implications for improving outcomes related to social, emotional, and behavioral functioning and also reduce the level of symptom impairment. Utilizing these interventions in the preschool period, when most of these developmental disorders emerge, may provide additional information on the trajectories and chronicity of these disorders. Further, targeting EF domains helped to generalize skills in a practical sense, such that preschoolers were also showing improve classroom behaviors, such as self-
regulation, which is important for later grade advancement and academic achievement (Diamond, 2012; Diamond, Barnett, Thomas, & Munro, 2007; Diamond & Lee, 2011).
### Table 1

**Means and Standard Deviations of Clusters on ALI Subscales**

<table>
<thead>
<tr>
<th>ALI subscales</th>
<th>Cluster Membership</th>
<th></th>
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<th></th>
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<tr>
<td></td>
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<td>2 (N=26)</td>
<td>3 (N=20)</td>
<td>4 (N=13)</td>
<td>F</td>
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<td>Comprehension †</td>
<td>3.68&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3.02&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>2.80&lt;sub&gt;ac&lt;/sub&gt;</td>
<td>1.94&lt;sub&gt;ac&lt;/sub&gt;</td>
<td>14.02***</td>
</tr>
<tr>
<td></td>
<td>(0.69)</td>
<td>(0.61)</td>
<td>(0.76)</td>
<td>(0.62)</td>
<td></td>
</tr>
<tr>
<td>Production †</td>
<td>3.71&lt;sub&gt;a&lt;/sub&gt;</td>
<td>2.99</td>
<td>2.79&lt;sub&gt;a&lt;/sub&gt;</td>
<td>2.03&lt;sub&gt;a&lt;/sub&gt;</td>
<td>7.14***</td>
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<tr>
<td></td>
<td>(0.84)</td>
<td>(0.97)</td>
<td>(0.97)</td>
<td>(0.96)</td>
<td></td>
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<tr>
<td>Rephrase †</td>
<td>3.60&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3.14&lt;sub&gt;b&lt;/sub&gt;</td>
<td>3.09&lt;sub&gt;c&lt;/sub&gt;</td>
<td>2.22&lt;sub&gt;abc&lt;/sub&gt;</td>
<td>6.26**</td>
</tr>
<tr>
<td></td>
<td>(0.72)</td>
<td>(0.75)</td>
<td>(0.82)</td>
<td>(0.77)</td>
<td></td>
</tr>
<tr>
<td>Spontaneity †</td>
<td>3.83</td>
<td>3.31</td>
<td>3.43</td>
<td>3.00</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>(0.96)</td>
<td>(1.08)</td>
<td>(1.04)</td>
<td>(1.10)</td>
<td></td>
</tr>
<tr>
<td>Listening †</td>
<td>3.33&lt;sub&gt;a&lt;/sub&gt;</td>
<td>2.87&lt;sub&gt;b&lt;/sub&gt;</td>
<td>2.81&lt;sub&gt;c&lt;/sub&gt;</td>
<td>1.75&lt;sub&gt;abc&lt;/sub&gt;</td>
<td>6.42**</td>
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<tr>
<td></td>
<td>(0.78)</td>
<td>(0.95)</td>
<td>(0.90)</td>
<td>(0.53)</td>
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<tr>
<td>Fluency †</td>
<td>3.78&lt;sub&gt;a&lt;/sub&gt;</td>
<td>2.83&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3.04</td>
<td>2.44&lt;sub&gt;a&lt;/sub&gt;</td>
<td>5.19**</td>
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<tr>
<td></td>
<td>(0.95)</td>
<td>(1.02)</td>
<td>(0.94)</td>
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<tr>
<td>Total Language ‡</td>
<td>21.92&lt;sub&gt;a&lt;/sub&gt;</td>
<td>18.17&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>17.95&lt;sub&gt;a&lt;/sub&gt;</td>
<td>13.38&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>7.86***</td>
</tr>
<tr>
<td></td>
<td>(4.31)</td>
<td>(4.65)</td>
<td>(4.44)</td>
<td>(3.32)</td>
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Note. Higher scores indicate better language functioning. Standard deviations appear in parentheses below means. Means with differing subscripts within rows are significantly different at the p < .006 level based on Bonferroni adjusted post hoc comparisons. † = Average scores ranging from 1 to 5. ‡ = Average scores ranging from 1 to 20. ** = p < .01. *** = p < .001.
Table 2

*Means and Standard Deviations of Clusters on CRS-P Subscales*

<table>
<thead>
<tr>
<th>CRS-P subscales</th>
<th>Cluster Membership</th>
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<th>$\eta^2$</th>
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<td>3 (N=20)</td>
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<td>Conduct Problems</td>
<td>44.65$_{ab}$</td>
<td>46.93$_{ab}$</td>
<td>55.56$_{ab}$</td>
<td>69.11$_{b}$</td>
<td>21.86***</td>
<td>0.46</td>
</tr>
<tr>
<td>Learning Problems</td>
<td>44.05$_{abc}$</td>
<td>62.96$_{ac}$</td>
<td>70.16$_{bc}$</td>
<td>85.33$_{c}$</td>
<td>26.88***</td>
<td>0.51</td>
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<tr>
<td>Psychosomatic Problems</td>
<td>(8.78)</td>
<td>(14.59)</td>
<td>(12.94)</td>
<td>(13.01)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impulsive Problems</td>
<td>45.60</td>
<td>52.56</td>
<td>49.76</td>
<td>53.56</td>
<td>1.43</td>
<td>0.05</td>
</tr>
<tr>
<td>Hyperactive Problems</td>
<td>(6.51)</td>
<td>(14.70)</td>
<td>(11.70)</td>
<td>(17.42)</td>
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</tr>
<tr>
<td>Anxiety</td>
<td>44.00$_{abc}$</td>
<td>53.56$_{a}$</td>
<td>51.56$_{b}$</td>
<td>58.56$_{c}$</td>
<td>7.54***</td>
<td>0.23</td>
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<tr>
<td>Hyperactivity Index</td>
<td>43.90$_{abc}$</td>
<td>52.78$_{abc}$</td>
<td>66.08$_{bc}$</td>
<td>80.44$_{c}$</td>
<td>49.82***</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Note. Higher scores indicate greater levels of impairment. Standard deviations appear in parentheses below means. Means with differing subscripts within rows are significantly different at the p < .008 level based on Bonferroni adjusted post hoc comparisons. *** = p < .001.
Table 3

*Means and Standard Deviations of Clusters on GARS Subscales*

<table>
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<tr>
<th>GARS subscales</th>
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<th></th>
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<tr>
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<td>2 (N=26)</td>
<td>3 (N=20)</td>
<td>4 (N=13)</td>
<td></td>
<td></td>
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<tr>
<td>Stereotyped Behaviors†</td>
<td>1.70_{ab}</td>
<td>3.63_{ab}</td>
<td>6.81_{a}</td>
<td>8.67_{b}</td>
<td>26.65***</td>
<td>0.51</td>
</tr>
<tr>
<td>Communication‡</td>
<td>1.90_{abc}</td>
<td>3.89_{ac}</td>
<td>5.65_{bc}</td>
<td>8.89_{c}</td>
<td>19.25***</td>
<td>0.43</td>
</tr>
<tr>
<td>Social Interaction‡</td>
<td>1.45_{abc}</td>
<td>3.22_{ac}</td>
<td>4.46_{bc}</td>
<td>8.33_{c}</td>
<td>30.38***</td>
<td>0.54</td>
</tr>
<tr>
<td>Developmental Disturbances†</td>
<td>3.40_{a}</td>
<td>3.37_{a}</td>
<td>3.96</td>
<td>6.22_{a}</td>
<td>3.52*</td>
<td>0.20</td>
</tr>
<tr>
<td>Autism Quotient‡</td>
<td>47.35_{ab}</td>
<td>56.85_{ab}</td>
<td>68.23_{ab}</td>
<td>86.67_{b}</td>
<td>26.94***</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>(N=23)</td>
<td>(N=26)</td>
<td>(N=20)</td>
<td>(N=13)</td>
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<tr>
<td></td>
<td>(1.49)</td>
<td>(2.50)</td>
<td>(2.61)</td>
<td>(3.20)</td>
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<tr>
<td></td>
<td>(1.17)</td>
<td>(2.72)</td>
<td>(2.86)</td>
<td>(2.62)</td>
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<tr>
<td></td>
<td>(0.95)</td>
<td>(2.11)</td>
<td>(2.02)</td>
<td>(2.06)</td>
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<tr>
<td></td>
<td>(2.26)</td>
<td>(2.57)</td>
<td>(2.41)</td>
<td>(2.17)</td>
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<tr>
<td></td>
<td>(6.31)</td>
<td>(13.07)</td>
<td>(12.91)</td>
<td>(14.58)</td>
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</tr>
</tbody>
</table>

Note. Higher scores indicate greater levels of impairment. Standard deviations appear in parentheses below means. Means with differing subscripts within rows are significantly different at the p < .008 level based on Bonferroni adjusted post hoc comparisons. † = Standard scores have a mean of 10 and a standard deviation of 3. ‡ = Standard scores have a mean of 100 and a standard deviation of 15. * = p < .05. *** = p < .001.
Figure 1. Clusters based on BRIEF-P subscale ratings within a sample of 82 preschool children. INH=Inhibition, SHFT=Shift, EC=Emotion Control, WM=Working Memory, PO=Planning and Organization. Higher scores indicate greater impairment.
Figure 2. Mean Based Differences based on Repeated Measures ANOVA of 82 preschool children across BRIEF-P subscale ratings. INH=Inhibition, SHFT=Shift, EC=Emotion Control, WM=Working Memory, PO=Planning and Organization. Higher scores indicate greater impairment.
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