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Developmental Functioning of Infants and Toddlers with Neurodevelopmental Disorders

Megan Callahan

DEVELOPMENTAL FUNCTIONING OF INFANTS AND TODDLERS WITH NEURODEVELOPMENTAL DISORDERS

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Megan Callahan
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Abstract

Autism spectrum disorder (ASD), epilepsy, and cerebral palsy (CP) are some of the most common neurodevelopmental disorders among children with prevalence rates of 1.85% (Maenner et al., 2020), 1.2% (Zack & Kobau, 2017), and between 0.21 and 0.31% (Christensen et al., 2013), respectively. These neurodevelopmental disorders are highly comorbid with each other and with other disorders, such as intellectual disability (ID). While previous research has investigated developmental functioning in these neurodevelopmental disorders, it has primarily focused on only two at a time and in older children or adults. The current study aimed to investigate developmental functioning in these neurodevelopmental disorders and an atypical control group using the Battelle Developmental Inventory, Second Edition (BDI-2). The current sample included four groups (i.e., ASD, seizures, CP, atypical control), with 253 infants and toddlers in each. The results indicated significant differences in overall developmental functioning, in addition to individual subdomains of the BDI-2. These findings provide the basis for further research to investigate comorbidities of the three neurodevelopmental disorders and parse out the impact of ID.

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by impairments in social communication and the presence of restricted, repetitive behaviors and interests (American Psychiatric Association, 2013). The rate of ASD continues to rise, with the last prevalence study reporting 1 in 54 individuals and a male to female ratio of 4.1:1 (Maenner et al., 2020). It has been reported to be comorbid with various disorders and impairments such as intellectual disability (ID), Down syndrome, Cerebral Palsy (CP), seizure disorders, inattention, impulsivity, challenging behaviors, and feeding problems (Matson et al., 2011; Christensen et al., 2019)

The aim of the current study is to further investigate differences in developmental functioning in infants and toddlers with ASD, seizures, and CP compared to atypically developing controls. Groups based on ASD, CP diagnoses, the presence of seizures, and atypically developing peers were compared to illuminate any differences in total developmental functioning (i.e., total DQ), and developmental subdomains (i.e., Adaptive, Personal-Social, Communication, Motor, Cognitive). Further, the study will expand the existing body of literature, which has focused primarily on older children, adolescents, and adults by investigating a younger sample.

Autism Spectrum Disorder

History of ASD

The history of ASD has three key players: Leo Kanner (1894-1981), Hans Asperger (1906-1980), and Lorna Wing (1928-2014). The word ‘autistic’ was originally used to describe characteristics of individuals with schizophrenia, coined by Eugen Bleuler (Lyons & Fitzgerald,

2007; Verhoeff, 2013). Specifically, it referred to the withdrawal from reality (Verhoeff, 2013). Autism was thought to be an early form of child schizophrenia until 1979, when the idea was abandoned (Wolff, 2004). The first publication regarding what we know today as autism appeared in 1943 written by Kanner, entitled, 'Autistic disturbances of affective contact', published in *The Nervous Child*. This was the first systematic account of autism, in which he described 11 children and observed a lack of communicative use of language, preservation of sameness, restricted interest in activities, and stereotypical and repetitive patterns of behavior (Kanner, 1943). Kanner introduced the term 'early infantile autism' the next year, 1944, to describe this phenomenon (Harris, 2018). While he originally believed this to be an innate disorder, writing that these children "have come into the world with the innate inability to form the usual, biologically provided affective contact" (Kanner, 1943), he later focused on psychogenic factors such as obsessive traits, emotional coldness, and lack of affect in the parents, categorizing it as a psychobiological disorder (Verhoeff, 2013).

In 1944, Hans Asperger published 'Autistic psychopathy in childhood'; however, Asperger's work would not become widely known until Wing described his work and his thesis was translated into English in 1991 by Uta Frith (Lyons & Fitzgerald, 2007). His original study examined four children who were described with 'a disturbance of adaption to the social environment' (Asperger, 1944/1991). In addition, he noted various characteristics congruent with current ASD diagnoses such as: odd speech patterns, flat affect, limited gestures, hyper- or hyposensitivity to noise, and odd and limited interests. He also noted an absence of humor, an 'aristocratic' appearance, over-sensitivity to criticism, manipulative, vindictive and antisocial acts, absence of shame and guilt, and egocentrism. Lastly, he noted a 'gift for logical abstract and original thinking'. He believed his disorder to be distinct from Kanner's work, citing a difference

in the use of communication and language, and later did not accept the term autism spectrum disorder when discussed in an interview in 2016 (Verhoeff, 2013; Harris, 2018; Donvan & Zucker, 2016).

Diagnostic Criteria for ASD

Autism first appeared in the Diagnostic and Statistical Manual, Third edition (DSM III; American Psychiatric Association, 1980) as 'Infantile Autism,' classified as a pervasive developmental disorder. It was defined as having an onset before 30 months with three essential features: 1) lack of responsiveness to others, as noted by lack of eye contact and facial responsiveness, indifference or aversion to physical contact, and lack of cooperative play and friendships as the child ages; 2) communication deficits, in both verbal and nonverbal skills such as echolalia, atypical grammatical structure, pronoun reversals, and lack of gestures; and 3) atypical responses to aspects of the environment (e.g., resistance to change, peculiar interest in or attachments to objects). The DSM-III also noted associated features such as under- or over-responsiveness to stimuli, repetitive body movements, and low intellectual quotient scores (IQ). Infantile Autism could be diagnosed with these criteria in the absence of delusions, hallucinations, loosening of associations, and incoherence as seen in schizophrenia.

Seven years later, a revised manual was published and changed the disorder to Autistic Disorder with broadened criteria. The DSM III-R (American Psychiatric Association, 1987) listed three diagnostic criteria domains for Autistic Disorder: 1) qualitative impairment in reciprocal social interaction, such as lack of awareness to others' existence or feelings, impaired imitation, abnormal social play, and impairment in peer relationships; 2) qualitative impairment in verbal and nonverbal communication and in imaginative activity, such as lack of babbling or gesturing, lack of eye contact and abnormal body posture, monotonous tone, and echolalia; and

3) markedly restricted repertoire of activities and interests, such as stereotyped body movements (e.g., spinning, body rocking), preoccupation with parts of objects or attachment to objects, insistence of routines, restricted interests. The individual must exhibit at least eight of sixteen total items, and at least two from the first domain, one from the second, and one from the third. The DSM-III-R expanded the age range of onset and included a specifier if onset was after 36 months of age.

The subsequent version, the DSM IV (American Psychiatric Association, 2000) divided pervasive developmental disorder into five diagnoses: Autistic Disorder, Rett's Disorder, Child Disintegrative Disorder (CDD), Asperger's Disorder, and Pervasive Developmental Disorder, Not Otherwise Specified (PDD-NOS). Autistic Disorder did not change much from the DSM-III-R with three criteria: qualitative impairment in social interaction; qualitative impairment sin communication; and restricted repetitive and stereotyped patterns of behavior, interests, and activities. It required an onset in either social interaction, language use, or symbolic or imaginative play before three years of age. Rett's Disorder diagnostic criteria included normal development and normal head circumference at birth until a deceleration of head growth occured between 5 and 48 months of age. In addition, the child regressed in hand skills and social skills. The child started engaging in stereotyped hand movements and have poorly coordinated movements, such as walking. CDD was diagnosed by a loss of skills in at least two of either language, social skills or adaptive behavior, bowel or bladder control, play, or motor skills before 10 years of age. In addition, the individual exhibited abnormal functioning in at least two of either social impairment, communication deficits, or restricted, repetitive, and stereotyped behavior, interests, and activities. Asperger's Disorder had two diagnostic criteria: deficits in social interaction (e.g., eye contact, gestures, lack of peer relationships, not sharing enjoyment or

interests) and restricted repetitive and stereotyped patterns of behavior, interests, and activities. Lastly, PDD-NOS was diagnosed for any child with severe and pervasive impairment of social interaction and communication, with stereotyped behavior, interests, and activities but they didn't meet criteria for the previous Pervasive Developmental Disorders, Schizophrenia, Schizotypal personality disorder, or Avoidance personality disorder.

The DSM-5 (American Psychological Association, 2013) replaced all four sub-groups with an umbrella autism spectrum disorder (ASD), categorized as a neurodevelopmental disorder instead of a Pervasive Developmental Disorder. Under the new definition, children who previously met criteria for Rhett syndrome or childhood disintegrative disorder did not meet criteria for an ASD diagnosis due to Rhett syndrome not listing social deficits and CDD involving cognitive decline (Harris, 2018). The DSM-5 also reduced the criteria domain to social communication deficits and repetitive and restricted behaviors. In addition, the DSM-5 includes atypical sensory modulation, similar to Kanner's original observations (Harris, 2018).

There has been some debate over the removal of Asperger's Syndrome from the DSM-5. However, the research has shown there is little difference between Asperger's and 'high-functioning' autism in regards to clinical and demographic characteristics, comorbidity, treatment response, and prognosis (Verhoeff, 2013). One study found that the greatest predictor of an individual receiving a diagnosis of Asperger's over ASD was the clinic in which the diagnosis was received, over the characteristics of the individual (Lord et al., 2012).

The current diagnostic criteria consist of two domains: persistent deficits in social communication and interaction; and restricted, repetitive patterns of behaviors, interests, or activities. The social and communication domain consists of social-emotional reciprocity, nonverbal communication, such as eye contact and gestures, and developing, maintaining, and

understanding relationships. The restricted, repetitive behaviors domain is met if the individual displays at least two of the following: stereotyped or repetitive movements, use of objects, or speech; resistance to change; restricted and fixated interests; and atypical reactions to sensory input.

Prevalence of ASD

Rates of ASD have been increasing substantially since its first case. In the last twenty years, it has risen from 1 in 150 children to 1 in 54, in 2016, according to the Centers for Disease Control and Prevention, using the Autism and Developmental Disabilities Monitoring Network (Autism and Developmental Disability Monitoring Network (ADDMN), 2007; Maenner et al., 2020). ASD is a little over four times more prevalent in boys than girls (Maenner et al., 2020). A similar study in Europe found prevalence rates of ASD between 0.48 – 3.13% as well as ASD being between three and five times more prevalent in males (Delobel-Ayoub et al., 2019).

Research suggests reliable diagnoses can be made as early as 16 months of age, with the median age of first evaluations between 29 and 46 months of age (Pierce et al., 2019; Maenner et al., 2020). Factors such as race, ethnicity, education, and family income have been associated with later diagnoses (Dickerson et al., 2017).

Developmental Functioning

ASD severity is associated with impairments in adaptive behavior (Golya & McIntyre, 2018). Preschool children with ASD score poorly in areas such as self-care, indicating a delay in functioning in daily living skills (Jasmin et al., 2009). For adaptive skills, children showed the poorest performance in the personal sub-domain, which includes eating, drinking, bathing, toileting, grooming, dressing and health care (Jasmin et al., 2009). One study has demonstrated that motor skills and visual-motor integration are positively correlated with daily living skills

(Jasmin et al., 2009). Sensori-motor variables are significantly correlated with functional skills, even when cognitive level was taken into account (Jasmin et al., 2009). Studies have examined how children with autism score on overall developmental milestones. One study found they were scoring nearly two standard deviations below the mean on domains for adaptive skills, with higher scores of autism symptomology being related to lower scores on the domains (Golya & McIntyre, 2018).

With regards to social functioning, recent studies have shown symptom severity has significant effects on interpersonal relationships, play and leisure time, and coping skills; of these, interpersonal relationships were the most impacted (Golya & McIntyre, 2018). In the same study, mild autism symptoms were associated with more delays in socialization and less in communication and daily living skills, whereas severe autism symptoms were associated in more delays in socialization and communication with lesser delays in daily living skills (Golya & McIntyre, 2018). The gap between autism severity groups was the largest for communication and, regardless of severity group, children with ASD scored low in socialization (Golya & McIntyre, 2018). The gap in socialization skills between children with ASD and neurotypical peers increases with age (Golya & McIntyre, 2018).

Similarly, young children with autism have significant motor delays which become more pronounced with age (Lloyd et al., 2013), with a distinct deviation around fifteen years old (Travers et al., 2017). One study found that 57% of participants had an overall motor delay. 63% of children with a significant gross motor delay and 53% with a fine motor delay and showed significant differences from norms (Jasmin et al., 2009). The worst motor performances were in locomotion, object manipulation such as kicking, throwing, and catching a ball, and grasping (Jasmin et al., 2009). They also found that gross motor skills were correlated with sensory

seeking and touch processing, suggesting difficulties with gross motor skills could be explained by atypical somatosensory responses (Jasmin et al., 2009). Another study also found that motor skills are related to current and future daily living skills (Travers et al., 2017).

Comorbid Conditions

Research into comorbid conditions with ASD has been ongoing and has yielded articles on various medical diagnoses and conditions. Research has found that around 70% of individuals with ASD have a comorbid psychiatric disorder and 41% have two or more comorbid disorders (Leyfer et al., 2006; Simonoff et al., 2008). One common comorbid psychiatric disorders is anxiety. A meta-analysis by Hollocks et al. (2017) found a pooled prevalence rate of 27% for any co-occurring anxiety disorder. Further, they reported lifetime prevalence rates for social anxiety (20%), obsessive compulsive disorder (OCD; 22%), generalized anxiety disorder (26%), panic/agoraphobia (18%), posttraumatic stress disorder (PTSD; 5%), specific phobia (31%), and separation anxiety (21%; Hollocks et al., 2017). A study by Leyfer et al. (2006) found prevalence rates for obsessive compulsive disorder, specific phobia, and separation anxiety of 37%, 44%, and 12%, respectively. Another common comorbid disorder is depression. The prevalence rate for anxiety disorders ranges between 0.9% - 37% (Simonoff et al., 2008; Leyfer et al., 2006; Hollocks et al., 2017). Hudson et al. (2018) found a pooled lifetime prevalence of 14.4%. Factors such as IQ have been positively correlated with depression, such that individuals with ASD and lower IQ have a lower prevalence rates of depression (Hudson et al., 2018; Hollocks et al., 2017).

Although the DSM-IV prohibited the co-occurring diagnoses of ASD and ADHD, the DSM-5 does not have such a restriction. Research has found a prevalence rate of comorbid ASD and ADHD between 28-78% (Simonoff et al., 2008; Leyfer et al., 2006; Antshel & Russo, 2019;

Lee & Ousley, 2007). A study by Rau and colleages (2020) found a prevalence rate of comorbid ADHD of 61% with a further breakdown, noting that 76.8% of those cases present with ADHD combined, 19.7% with ADHD-inattentive, 0.02% with ADHD-hyperactive/impulsive, and 0.02% unspecified or other.

Seizures

Another comorbid disorder is epilepsy, a neurological seizure disorder. A national study found a prevalence rate of 1.2%, with 470,000 children diagnosed with epilepsy (Zack & Kobau, 2017). There are two classifications of seizures, generalized and partial/focal. Generalized seizures start at one point within bilaterally distributed network, but do not necessarily include the entire cortex (Berg et al., 2010). On the other hand, focal seizures are contained within networks in one hemisphere (Berg et al., 2010). In an epidemiological study of epilepsy in Europe, Forsgren et al. (2005) found that the prevalence rate of seizures increases by age. The prevalence rate was found to be 4.5 to 5 per 1000 children and adolescents, six per 1000 individuals between 20 to 65 years of age, and seven per 1000 for individuals 65 and older.

Types of seizures

Generalized seizures include absence seizures, tonic-clonic seizures, myoclonic seizures, and atonic seizures (Kutscher, 2006, pg. 20). Absence seizures are non-convulsive and last approximately 3 to 30 seconds followed by a halting of activity (McCagh, 2012, pg. 33; Kutscher, 2006, pg. 20). They have a sudden onset and cessation with a brief loss of consciousness after which normal activity is resumed. These seizures often begin in childhood or early adolescence. Atypical absence seizures are absence seizures in which automatisms, clonic, atonic, and tonic events are observed.

The other types of generalized seizures (tonic, clonic, tonic-clonic, atonic, and myoclonic) are convulsive (McCagh, 2012, pg. 33). Tonic refers to a sudden contraction of muscles, while clonic refers to when muscles relax and contract intermittently. Tonic-clonic is where the individual experiences tonic seizures followed by clonic seizures. Atonic seizures are characterized by a sudden decrease in muscle tone resulting in a nodding of the head or the patient falling to the floor. Myoclonic seizures involve clonic movements while falling asleep or waking up (McCagh, 2012, pg. 33).

Focal seizures include simple partial seizures, complex partial seizures, and partial seizures that evolve to secondary generalization (McCagh, pg. 32). Simple partial seizures are categorized by maintained consciousness and symptoms are related to the focal area of the seizure (McCagh, pg. 32). Simple partial seizures can be further categorized by motor, sensory, autonomic, and psychic seizures. Motor seizures are events such as the jerking of a limb, whereas sensory seizures involve either sensory, somatosensory, gustatory, or vertiginous symptoms. Autonomic seizures include symptoms such as sweating, vomiting, or flushing. Lastly, although uncommon, are psychic seizures which are categorized by dysphasia, memory impairment, and a sense of déjà vu. Complex partial seizures are characterized by impaired consciousness with psychic disturbance and automatisms, often accompanied by an aura before the seizure (McCagh, pg. 33). The third type of partial seizure are those that spread to be categorized as a generalized motor seizure, which can be tonic, clonic, or tonic-clonic.

Etiology

Seizures can be caused by various factors and fall into the following categories: structural, genetic, infectious, metabolic, immune, and unknown. The structural causes include lesions, trauma, infection, or disease (Harris & Angus-Leppan, 2020; Berg et al., 2010). Cortical

development malformations can be categorized as structural or genetic (Harris & Angus-Leppan, 2020). Genetic factors, referred to as idiopathic epilepsy, account for 25% of epilepsies (Harris & Angus-Leppan, 2020). Infections, such as meningitis and encephalitis, are also contributing factors to seizures (Harris & Angus-Leppan, 2020).

Diagnoses

Electroencephalography (EEG) assists clinical decisions such as the type of seizure, risk of recurrence, and response to treatment (Harris & Angus-Leppan, 2020). Harris and Angus-Leppan (2020) note that 50% of people with epilepsy have a normal EEG. Magnetic Resonance Imaging (MRI) helps identify structural lesions or other neurological injuries (Harris & Angus-Leppan, 2020). Additional information is acquired through family history, patient history with drug and alcohol use, and patient and witness account of the seizures including prodromal symptoms, triggers, time of the seizure as well as where it took place, duration, and progression of the seizure (Harris & Angus-Leppan, 2020).

Developmental Functioning

One study by Matson and colleagues (2010) investigated developmental functioning in four groups: ASD with seizures, atypical with seizures, ASD without seizures, and atypical without seizures. They found that the ASD group scored lower on the developmental domains than atypically developing children, with the exception of communication and motor skills. They also found that the seizure group scored lower across developmental domains than children without seizures. Overall, they found that the group of co-occurring ASD and seizures showed the greatest impairment, followed by seizure, ASD, and lastly, the atypical group showed the least impairment.

Cerebral Palsy

Cerebral palsy is a group of neurodevelopmental disorders caused by damage to the brain before or shortly after birth (Mayo Clinic, 2020). It is characterized by impaired movement and muscle tone or posture (Mayo Clinic, 2020). Cerebral palsy's effect is wide in scope with some people walking independently, while others need assistance (Mayo Clinic, 2020). More specifically, an international workshop defined cerebral palsy in 2006 as, "a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behavior, by epilepsy, and by secondary musculoskeletal problems" (Rosenbaum et al., 2006). Further, they define four components of classification. First, motor abnormalities, regarding muscle tone (hypertonia and hypotonia), movement (spasticity, ataxia, dystonia, athetosis), and functional abilities. Secondly, the presence of accompanying impairments, such as seizures, hearing or vision impairments, or attention, behavior, communication, and/or cognitive deficits. However, they note that defining the accompanying impairments is age-dependent and may be hard to characterize in young children. The third component includes anatomical findings, regarding the parts of the body affected by motor impairments and neuro-imaging findings such as ventricular enlargement, white matter loss, or brain anomalies, via CT or MRIs. Lastly, causation and timing, regarding if there is clearly defined issue and the time frame when the injury occurred.

A meta-analysis by Oskoui et al. (2013) found the pooled prevalence of CP to be 2.11 per 1000, whereas a U.S. national prevalence study found the rate to be 3.1 per 1000 children aged 8 (Christensen et al., 2013). They found around 77.4% of children with cerebral palsy have a

spastic subtype, 8.4% had non-spastic, and 14.2% had other subtypes including mixed and not otherwise specified (Christensen et al., 2013). Another study compared registry data from Victoria, Australia to data found via systematic review. Their systematic review found 65-95% of individuals with cerebral palsy have the spastic subtype, 1-11% have ataxia, and 2-15% have dyskinesia (Reid et al., 2011). Their registry data found 90.6% have the spastic subtype, 5% with ataxia, and 4.4% with dyskinesia (Reid et al., 2011).

Research has shown cerebral palsy to be comorbid with ASD, intellectual disability, and epilepsy. The U.S. national prevalence study found ASD to be comorbid with cerebral palsy at a rate of 6.9% (Christensen et al., 2013). Another study with a European sample found the comorbid prevalence rate to be 8.7%, varying by region between 4.0 – 16.7% (Delobel-Ayoub et al., 2017). Research has shown children with comorbid ASD and cerebral palsy (ASD/CP) had a higher rate of non-spastic CP compared to children with CP alone (Christensen et al., 2013), although the significance has been contested (Delobel-Ayoub et al., 2017). Studies suggest 30-41% of participants with cerebral palsy also have epilepsy (Delobel-Ayoub et al., 2017; Christensen et al., 2013), while 46.9% were found to have comorbid ID.

Developmental Functioning

Regarding motor function, research has shown individuals with CP vary widely in skills (Ostensjo et al., 2003; Park, 2018). A study by Park (2018) found that children with CP have significant individual differences during the first year of life among other children with CP, but have similar patterns of daily living skill development. They also found a positive relationship between the initial mobility score and rate of change in daily living skills. Similarly, another study found that functioning in daily life was related to the severity of mobility restrictions, specifically that gross motor skills significantly predicted mobility, self-care, and social

functioning (Ostensjo et al., 2003). However, one study indicates that gross motor function is less important in daily-life mobility for children with less severe CP (Smits et al., 2010). One study by Tan et al. (2019) found that individuals with CP alone score similarly on communication and social domains of the Vineland Adaptive Behavior Scales (VABS; Sparrow et al., 1984) as typically developing peers. They found trends of development for receptive communication stabilizing in childhood, expressive communication and interrelationships in adolescence, and written communication, play and leisure, and coping in early adulthood, regardless of motor ability.

Intellectual Disabilities

Intellectual Disabilities (ID) is defined as "limitations both in intellectual functioning and adaptive behavior" according to the American Association on Intellectual and Developmental Disabilities (2010). Similarly, the DSM-5 (2013) diagnostic criteria includes deficits in intellectual functioning and adaptive functioning. In addition, the DSM-5 requires the onset of intellectual and adaptive deficits to occur during the developmental period. Intellectual functioning includes mental processes such as reasoning, problem solving, planning, abstract thinking, judgement, academic learning, and learning from experience. Adaptive functioning includes activities of daily living such as communication, social participation, and independent living and adaptive deficits must occur across multiple environments (e.g., home, school, work).

A meta-analysis by Maulik and colleagues (2011) calculated a prevalence rate of 10.37 per 1000 individuals. Across the lifespan, males had a higher prevalence than females, with a ratio varying between .7 and .9 for adults and between .4 and 1.0 in children and adolescents. Factors such as country income level, population type, age group, study design, and sampling

strategy influenced the rate of ID. Low and middle-income countries had higher levels of ID, with prevalence rates of 16.41 and 15.94 respectively, compared to 9.21 in high-income countries (Maulik et al., 2011). Intellectual disabilities have been linked with many potential causes, such as environmental, genetic, social, and behavioral. Genetic factors include Down syndrome, the most common genetic factor in the United States (1 in 700 births), and Fragile X, the most common known inherited factor (1 in 5,000 males; Boat et al., 2015). Environmental causes include factors such as exposure to toxins (e.g., alcohol, lead), nutritional deficiencies, brain radiation or infections, brain injury, and maternal infections (e.g., rubella, cytomegalovirus; Boat et al., 2015).

Similarly, global developmental delay (GDD) is defined by failing to "meet expected developmental milestones in several areas of intellectual functioning" in children under 5 years of age (DSM-5, 2013). There must be delays in at least two of the following domains: motor skills, speech and language, socialization, or activities of daily living (Shevell et al., 2003). The current estimate of GDD in the general population is 1 to 3% (Shevell et al., 2003). However, not all children with GDD go on to receive a diagnosis of ID (Shevell et al., 2003).

A study by Shevell and colleagues (2005) investigated developmental functioning in preschoolers with GDD and developmental language impairment. Children with GDD scored significantly lower on all domains of the Battelle Developmental Inventory (Glascoe and Byrne, 1993) except for communication (i.e., total DQ, personal-social, adaptive, motor, and cognitive), and all domains of the VABS (i.e., total, communication, socialization, daily living skills; Sparrow et al., 1984). Further, 17% of the GDD sample attended an integrated classroom, 29.8% attended an integrated classroom with support, and 53.2% attended a special class or school (Shevell et al., 2005).

Individuals with ID also often have difficulties with social communication, with 57.9% of an adult sample with ID reporting some level of communication difficulty, with 74.8% communicating verbally (Smith et al., 2020). The study also found that over half (55%) of the sample showed low levels of social participation. Similarly, over half (52.3%) reported having a best friend, in which 63.7% of cases was another individual with ID, 15.8% was a staff member, and 8.6% was a family member. Of the 55% of participants who reported difficulty in participating in social activities, only 27% of participants attributed this to communication or language problems (Smith et al., 2020).

Regarding motor skills, one study compared children with mild ID and borderline ID and found that a higher proportion of children with mild ID had motor problems (81.8% and 60.0%; Vuijk et al., 2010). Children with ID showed the most difficulty with manual dexterity (70.9% and 56.5%) and ball skills and balance (63.6% and 44.3%; Vuijk et al., 2010). Another study showed that individuals with ID score significantly lower on motor tests compared to typically developing peers, with a delay equivalent of 3 to 4 years (Rintala & Loovis, 2013).

Intellectual disability is highly comorbid with other neurodevelopmental disorders. Current estimates suggest ID occurs in approximately 40% of individuals with ASD (Arvio & Sillanpaa, 2003). Further, research suggests ID influences the gender ratio of ASD, as it increases to 2:1 male-to-female for individuals with comorbid ASD and ID (Halladay et al., 2015). Similarly, approximately 45% of individuals with CP were found to have comorbid ID (Delobel-Ayoub et al., 2017; Reid et al., 2018). Comorbid ID is implicated in later walking, non-ambulation, hypotonic and dyskinetic CP subtypes, and epilepsy (Reid et al., 2018). On the other hand, 16% of individuals with epilepsy have comorbid ID (Morgan et al., 2003), which is related to higher rates of ASD, behavioral problems, postictal psychosis, and both psychotic and

nonpsychotic disorders (van Ool et al., 2016). Comorbid disorders have implications in both diagnostic procedures as well as treatment plans. Assessments need to be robust in order to provide differential diagnoses, while dual diagnoses play a significant role in how to formulate treatment plans and setting realistic expectations.

Purpose

While there is a growing body of literature on neurodevelopmental disorders, there currently is a lack of research into how individuals with ASD, seizures, and CP compare to atypically developing peers. This gap of knowledge should be investigated to inform how these diagnoses impact developmental outcomes. Autism spectrum disorder has a prevalence rate of approximately 1.9% (1:54; Maenner et al., 2020). Similarly, epilepsy has a prevalence rate of 1.2% (Zack & Kobau, 2017). Cerebral palsy has the lowest prevalence rate of 0.2-0.3% (Oskoui et al., 2013; Christensen et al., 2013). The current research examining developmental functioning, tends to focus on one particular neurodevelopmental disorder, rather than how multiple interact. Others focus on two disorders (Matson et al., 2010; Burns & Matson, 2018; Hattier et al., 2012). In addition, research tends to focus on only one domain of development in older age groups (Golya & McIntrye, 2018; Jasmin et al., 2009; Travers et al., 2009; Ostenjo et al., 2003).

The current study aimed to examine the relationship between atypically developing controls, ASD diagnosis, and history of seizures, and CP diagnosis and the developmental outcomes. The current study was a retrospective study to investigate differences in developmental functioning in infants and toddlers with and without ASD, seizures, and CP. The results may have research implications in finding neurodevelopmental profiles in the various disorders, which will further information on how these disorders interact. The research base may also further clinical implications as these neurodevelopmental profiles and interaction of disorders may provide information to further earlier diagnoses of comorbidities and inform differential diagnoses.

Methods

Participants

This study consisted of 1012 participants ranged between 17 and 35 months of age (M = 25.80, SD = 4.68). Participants in this study were enrolled in EarlySteps, Louisiana's statewide early intervention program under the Individuals with Disabilities Education Act, Part C. Children qualify for EarlySteps services if they have or are at risk for a developmental delay and are under three years of age. Participants included in this analysis were between 17 and 37 months at the time of assessment. The data were extracted from an existing dataset containing assessment information but without identifying information.

The participants were assigned to one of four groups: atypically developing controls (Atyp), autism spectrum disorder (ASD), seizures (Seiz), and cerebral palsy (CP). Participants were assigned to groups based on whether they met criteria for ASD and whether they had a reported history of seizures or a diagnosis of cerebral palsy. Diagnoses of ASD were given by a licensed clinical psychologist with more than 30 years of experience, based on an algorithm in accordance with the Diagnostic and Statistical Manual (*DSM-5*, American Psychiatric Association, 2013), using the Baby and Infant Screen for Children with aUtIsm Traits-Part 1 (BISCUIT; Matson, Boisjoli, & Wilkins, 2007) and Battelle Developmental Inventory, Second Edition (BDI-2; Newborg, 2005). The licensed psychologist was blind to the total BISCUIT scores. The algorithm combines clinically relevant BISCUIT items for each DSM-5 ASD diagnostic domain and presents the BDI-2 domain scores. The participants met criteria for ASD if they scored significantly on all three social communication domains and at least two of four restricted, repetitive patterns of behavior domains. In addition, the psychologist took into account

the personal-social and communication scores of the BDI-2. A history of seizures and classification of cerebral palsy were both based on parental report of previous diagnoses on the demographic subsection of the BISCUIT. The demographic subsection of the BISCUIT probes for information regarding parental concerns, age of milestones, medical history including current diagnoses and medications, as well as previous assessments for ASD, number of siblings, birth order, parental age at birth, and family history of ASD. Participants will be placed in the atypically developing control group (Atyp), if they do not meet criteria for ASD and did not report diagnoses of cerebral palsy, Down syndrome, global developmental disorder, developmental delay, intellectual disabilities, or a history of seizures. Therefore, the atypically developing control group consisted of participants with no diagnoses, allergies, chronic ear infections, and visual impairments. However, visual impairments did not include participants who are legally blind.

The dataset consisted of 27,408 cases. Participants were excluded from the analyses if they had missing data, such as either the relevant items of the BISCUIT-Part 1 or BDI-2 total DQ and developmental subdomains. In addition, if participants reported a genetic, neurological, or developmental disorder other than ASD, seizures, cerebral palsy, or global developmental delay (GDD), they were excluded from the analyses (e.g., traumatic brain injury, Fragile X syndrome, Down syndrome). Further, if duplicate cases were found in the database, any duplicates were deleted, while retaining the first entry. Lastly, any participants with comorbidities among the retained diagnoses were excluded (e.g., comorbid ASD and seizures, comorbid seizures and cerebral palsy). Figure 1 presented the total cases excluded from the analyses.

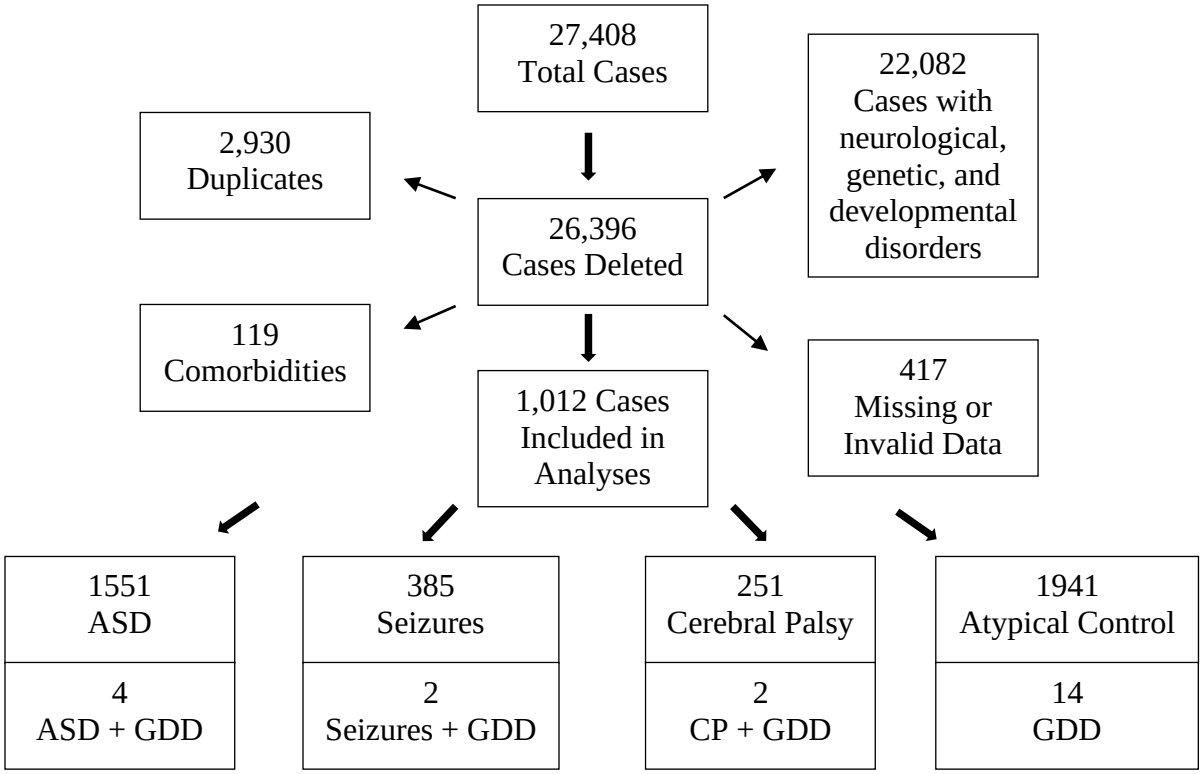

Figure 1. Case Exclusion Criteria

One thousand and twelve cases were included in the blocking procedure. Due to the unequal sample sizes across groups, cases were randomly selected to match the sample size of the smallest group (i.e., CP). In addition, the groups followed a block design, such that the group with the highest percentage of comorbid GDD (i.e., 0.79%) was retained across groups, such that two out of the 253 participants for each group had comorbid GDD. The comorbid GDD participants were randomly selected in both the ASD and the atypical control groups; however, since the seizure group only had two participants with GDD, both were included. Blocking was used in this study in an attempt to increase generalizability, as all three neurodevelopmental groups have high comorbidity rates with ID. Further, blocking was used rather than randomly selecting participants in order to control the impact GDD would have on the cognitive domains if the groups had unequal percentages of GDD.

The total sample consisted of 65% males (*n* = 658), 34.4% of females (*n* = 348), and 0.6% did not report or had missing data (*n* = 6). Further, the sample consisted of 40.3% African American individuals (*n* = 408), 48.0% Caucasian individuals (*n* = 486), 3.6% Hispanic individuals (*n* = 36), and 8.1% listed "other" for race or did not report (*n* = 82). The descriptive statistics for each group is provided below in Table 1.

Table 1. Demographic Statistics by Group

	Group			
	ASD	Seizures	CP	Atypical Control
Age	26.0	25.53	26.50	25.19
M (SD)	(4.47)	(4.65)	(4.60)	(4.90)
Gender				
Male	195 (77.1%)	149 (58.9%)	141 (55.7%)	173 (68.4%)
Female	55 (21.7%)	101 (39.9%)	112 (44.3%)	80 (31.6%)
Missing	3 (1.2%)	3 (1.2%)	0 (0%)	0 (0%)
Race/Ethnicity				
African American	104 (41.1%)	114 (45.1%)	102 (40.3%)	88 (34.8%)
Caucasian	112 (44.3%)	116 (45.8%)	118 (46.6%)	140 (55.3%)
Hispanic	12 (5.1%)	7 (2.8%)	10 (4.0%)	6 (3.4%)
Other	24 (9.5%)	16 (6.4%)	23 (9.1%)	19 (7.6%)

Measures

Baby and Infant Screen for Children with aUtIsm, Part 1

Baby and Infant Screen for Children with aUtIsm Traits, Part 1 (BISCUIT- Part 1, Matson et al., 2007). The BISCUIT is a parent-report measure for children between 17 and 37 months of age, consisting of three sections to evaluate autism symptomology, comorbid psychopathology, and challenging behaviors. Part 1 consists of 62 items to assess ASD symptoms related to verbal and nonverbal communication, socialization, and repetitive behavior and restricted interests. The parent can rate each item on a three-point Likert scale, comparing their child to same-aged peers. The scale consists of 0, indicating "not different; no impairment", 1 indicating "somewhat different; mild impairment", and 2 indicating "very different; severe impairment". A total score of 0-16 falls in the "No ASD/Atypical Development" range; a total of 17 to 38 falls in the "Possible ASD" range, and a score of 39 to 124 falls in the "Probable ASD" range. The BISCUIT-Part 1 has an estimated internal reliability of .87 and overall correct classification rate of .89 (Matson et al., 2007). The BISCUIT- Part 1 is used in the current study to assist in the DSM-5 diagnostic algorithm for ASD.

Battelle Developmental Inventory, Second Edition

Battelle Developmental Inventory, Second Edition (BDI-2, Newborg, 2005). The BDI-2 assesses the developmental skills of children between birth and 7 years 11 months old through informant-report and structured observation. It consists of five developmental domains: Adaptive, Personal-Social, Communication, Motor, and Cognitive. The BDI-2 had 450 items scored on a 3-point Likert scale. A score of 0 indicates "no ability in the skill", 1 indicating emerging ability" and 2 indicating "ability at the skill". The total score is a sum of each domain's

score and has a mean of 100 and a standard deviation of 15. The BDI-2 has a test-retest reliability estimate above .90 for each domain and total score (Newborg, 2005). Internal consistency was calculated between .98 and .99 for both domain and total scores. The BDI-2 is used in the current study to assess developmental functioning for each evidence from a meta-analysis and two subdomains (i.e., Personal-Social and Communication) assist in the DSM-5 diagnostic algorithm.

Procedure

The study was approved by the Louisiana State University Institutional Review Board and the Office for Citizens with Developmental Disabilities (OCDD) of the State of Louisiana, prior to data collection. Informed consent was obtained from parents of the children involved in the study prior to data collection.

The BISCUIT-Part 1 and the BDI-2 were administered as a part of a larger assessment battery that included both parent interviews and child observations. The assessments were conducted in the child's home or daycare by roughly 175 EarlySteps providers. The providers all held appropriate degrees and certifications or licensures in various fields such as occupational therapy, physical therapy, psychology, special education, social work, and speech-language pathology.

Statistical Analysis

G*Power 3.1, a statistical power analysis program, was used to determine the minimum sample sizes needed for adequate power using the four groups. An a priori power analysis, using a power of .80, alpha level of .05, and medium effect size of .30 yielded a suggestion of at least

128 participants, with 32 participants per group for the ANOVA analysis, and at least 28 total participants for the MANOVA.

Statistical analyses were conducted using SPSS 26.0. Bivariate and multivariate analyses were conduced to investigate two primary research questions: does overall developmental functioning differ by neurodevelopmental group (i.e., ASD, Seizures, CP, Atypical control) and does neurodevelopmental group impact developmental functioning across five domains (i.e., adaptive, personal-social, communication, motor, cognitive). Cronbach's alpha was calculated to determine the internal consistency of the two measures used in the study (i.e., BISCUIT-Part 1, BDI-2). Two chi-square analyses were performed to evaluate differences in gender and race and ethnicity between the groups. In addition, an analysis of variance (ANOVA) was conducted to determine differences in age between the groups.

In the current study, an ANOVA was conducted to determine the relationship between neurodevelopmental group and the overall developmental functioning. The groups (i.e., ASD, seizures, CP, atypical control) served as the independent variable (IV) and the BDI-2 total developmental quotient (DQ) served as the dependent variable (DV). Games-Howell post-hoc tests were utilized to further investigate group differences.

A multivariate analysis of variance (MANOVA) was conducted to determine the relationship between group and developmental subdomains. The groups again served as the IV while the five BDI-2 subdomains (i.e., adaptive, personal-social, communication, motor, cognitive) served as the DV. Separate ANOVAs were conducted to assess the group differences. A Bonferroni correction was applied in account of the multiple comparisons (p = .01). Lastly, Games-Howell post-hoc tests were used to follow up significant ANOVAs, since homogeneity of variance was violated (Field, 2013).

Results

Cronbach's alpha was calculated for the BISCUIT-Part 1 and the BDI-2 and found to be .97 and .90, respectively. The chi-square analysis indicated no significant differences based on race and ethnicity, $\chi^2(9) = 11.89$, $p = .220$. The association was small (Cohen, 1988), Cramer's V = .063. However, there was a statistically significant association between group and gender, $\chi^2(3) = 32.71$, $p < .0001$, although the association was small (Cohen, 1988), Cramer's V = .180. The count and adjusted residuals of gender is provided in Table 2.

Table 2. Crosstabulation of Group and Gender

Group	Gender	
	Male	Female
ASD	195	55
(Adjusted Residual)	(4.8)	(-4.8)
Seizures	149	101
(Adjusted Residual)	(-2.2)	(2.2)
CP	141	112
(Adjusted Residual)	(-3.7)	(3.7)
Atypical Control	173	80
(Adjusted Residual)	(1.1)	(-1.1)

A one-way ANOVA indicated statistically significant differences in age for the groups, F (3, 1350) = 6.654, $p < .0001$. There was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = .226$). Post-hoc analyses indicated significant differences between the ASD and atypical control groups ($p = .014$) and between the CP and atypical control groups ($p < .0001$). The CP group had the highest mean age ($M = 26.37$, $SD = 4.65$), followed by ASD ($M = 25.99$, $SD = 4.38$), then seizures ($M = 25.48$, $SD = 4.61$), lastly followed by the atypical control group ($M = 24.88$, $SD = 4.83$).

Preliminary assumptions were checked for the ANOVA, which indicated the presence of six outliers, which all fell outside of 2.5 standard deviations from the mean. As such, the outliers were winsorized to be 2.5 standard deviations from the mean. Following winsorizing the data, four outliers were identified. These outliers were retained as they did not appear to be due to data entry errors and fell within 2.5 SD of the mean. The total DQ variable was normally distributed, as assessed by the skewness and kurtosis values. According to Bryne (2010), skewness is considered normal if the value falls between -2 and +2, and kurtosis between -7 and +7. Homogeneity of variances was violated, as assessed by Lavene's test for equality of variances ($p < .0001$). Since homogeneity of variances was violated, a Welch ANOVA and the Games-Howell post hoc tests were used. According to the Welch ANOVA, the BDI-2 total DQ scores were statistically significantly different across groups, F (3, 548.73) = 37.94, $p < .0001$. The Games-Howell post-hoc tests indicated statistically significant differences between the ASD and seizure groups ($p = .003$), ASD and atypical control groups ($p < .0001$), seizures and atypical control ($p < .0001$), and CP and atypical control ($p < .0001$). However, a statistically significant difference was not found between the ASD and CP group ($p = .160$) and between the seizures

and CP group (p = .764). BDI-2 descriptive statistics for the total DQ scores across groups are provided in Table 1.

Preliminary assumptions were also examined prior to conducting the MANOVA. Thirty-four univariate outliers were found in the Adaptive (4), Personal Social (3), Communication (12), Motor (10), and Cognitive (6) domains of the BDI-2, all which fell outside of 2.5 SD of the mean. These outliers were not found to be due to data entry error. As such, the outliers were winsorized to be 2.5 SD from the mean. Following winsorizing the data, there were two outliers which were kept as they did not appear to be data entry errors and were within 2.5 SD of the mean. All dependent variables were deemed to meet normality, as evaluated by the skewness, between -2 and +2, and kurtosis values, between -7 and +7, according to Bryne (2010). According to Pearson's correlation, there was no multicollinearity, with correlations ranging between .501 and .707. Assessing scatterplots of BDI-2 subdomain scores in each group revealed linear relationships. Two multivariate outliers were identified (p < .001), according to the Mahalanobis distance critical value of 20.52. These multivariate outliers were retained as the MANOVA is robust to multivariate outliers with large sample sized (Laerd, 2018). In addition, the results did not vary when the MANOVA was run without the inclusion of the two multivariate outliers. Homogeneity of variance-covariance matrices was violated, as indicated by the Box's M Test of Equality of Covariances Matrices (p < .0001); given the equal sample sizes (n = 253), this violation was not a concern (Laerd, 2018). However, due to this violation, the Pillai's Trace was interpreted rather than the Wilks' Lamda, since it is less sensitive to this violation. The Games-Howell post-hoc tests were used to follow up the ANOVAs to account for the violation of homogeneity of variance for all domains (p < .0001).

There was a statistically significant difference between the groups on the combined developmental subdomains, Pillai's Trace = .514, F (15, 3018) = 41.55, $p < .0001$; *partial* η^2 = .171. Separate one-way ANOVAs were conducted, followed by a Bonferroni correction ($p < .01$) to account for multiple comparisons. There was a statistically significant difference across all developmental subdomains: the adaptive subdomain, F (3, 1008) = 26.536, $p < .0001$; *partial* n^2 = .073, the personal-social subdomain, F (3, 1008) = 45.741, $p < .0001$; *partial* n^2 = .120, the communication subdomain, F (3, 1008) = 38.142, $p < .0001$, *partial* n^2 = .102, the motor subdomain, F (3,1008) = 98.458, $p < .0001$, *partial* n^2 = .227, and cognitive subdomain, F (3, 1008) = 31,793, $p < .0001$, *partial* n^2 = .086.

The Games-Howell post-hoc tests indicated statistically significant group differences within each of the developmental subdomains. In the adaptive subdomain, significant differences were found between the ASD and Atypical control group ($p < .0001$), seizure and atypical control ($p < .0001$), and CP and atypical control ($p < .0001$). For the personal-social subdomain, significant differences were found between all groups ($p < .0001$), except for the seizure and CP group ($p = .866$). In the communication subdomain, significant differences were found between all groups ($p < .0001$), except for seizures and CP ($p = .315$), seizures and atypical control ($p = .078$), and CP and atypical control ($p = .960$). Further, significant differences were found between groups in the motor subdomain: ASD and CP ($p < .0001$), ASD and atypical control ($p < .0001$), seizure and atypical control ($p < .0001$), CP and atypical control ($p < .0001$). However, significant differences were not found between ASD and CP ($p = .074$) and seizures and CP ($p =.990$). Lastly, groups were found to have significant differences in the cognitive domain, including ASD and atypical control ($p < .0001$), seizures and atypical control ($p <.0001$), and CP

and atypical control ($p < .0001$). Group differences on the developmental subdomains are presented in Table 3.

Table 3. Group Differences in Developmental Subdomains

BDI-2 (Sub)Domain	Group			
	ASD	Seizures	CP	Atypical Control
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Total DQ	59.52 (22.45)[b,d]	68.53 (34.68)[a,d]	65.35 (38.45)[d]	83.79 (28.68)[a,b,c]
Adaptive	73.18 (12.40)[d]	77.19 (16.27)[d]	74.11 (16.83)[d]	83.97 (14.40)[a,b,c]
Personal-Social	77.34 (10.73)[b,c,d]	86.36 (14.93)[a,d]	85.31 (15.64)[a,d]	91.13 (11.90)[a,b,c]
Communication	62.16 (10.43)[b,c,d]	72.18 (16.95)[a]	74.95 (19.30)[a]	75.74 (16.40)[a]
Motor	88.38 (15.30)[c,d]	84.17 (19.70)[c,d]	74.06 (17.40)[a,b,d]	98.59 (11.70)[a,b,c]
Cognitive	71.66 (10.15)[d]	74.69 (13.16)[d]	74.32 (14.15)[d]	81.84 (11.32)[a,b,c]

Note: [a] significantly different from ASD group

[b] significantly different from Seiz group

[c] significantly different from CP group

[d] significantly different from Atyp group

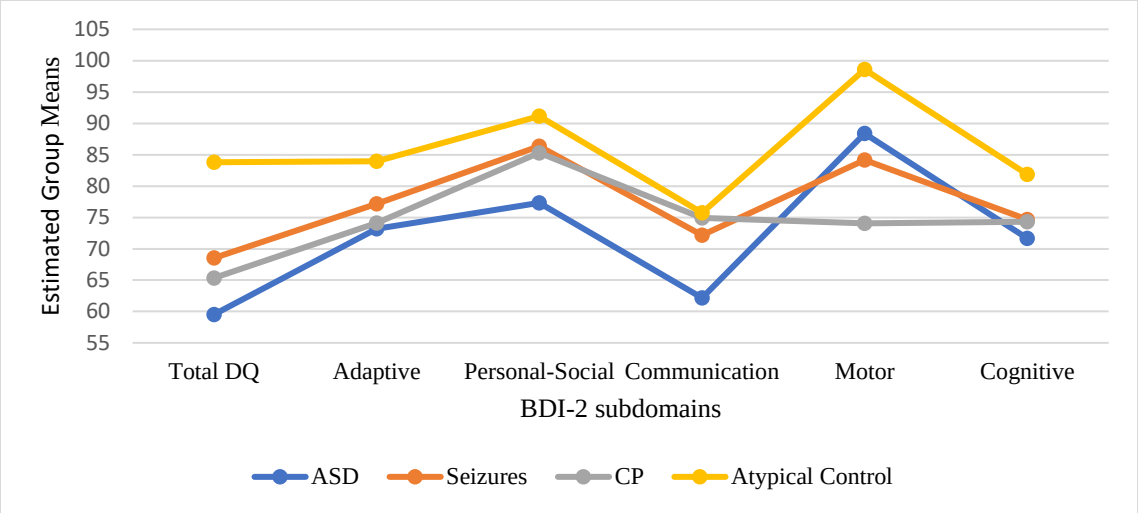

Figure 2. Estimated Group Mean BDI-2 Scores

Discussion

The current study investigated the relationship between neurodevelopmental diagnostic group (i.e., ASD, seizures, CP, atypical developing control) and developmental functioning overall and across five subdomains. There was a significant difference found between the neurodevelopmental groups (i.e., ASD, seizures, CP) and the atypical control group ($p < .0001$) and between the ASD and seizure group ($p = .003$) on the BDI-2 total DQ scores; with a general trend such that the atypical control group scored the highest ($M = 83.79$, $SD = 1.80$), followed by the seizure group ($M= 68.53$, $SD = 2.18$), the CP group ($M = 65.35$, $SD = 2.42$), followed lastly by the ASD group ($M = 59.52$; $SD = 1.41$).

With regards to the adaptive subdomain, the atypical control group was statistically different from each neurodevelopmental group. Significant differences were found between all groups in the personal-social subdomain, with the exception of the seizure and CP group. Similar results were found for the communication subdomain, with significant differences between all groups except for seizure and CP, seizure and atypical control, and CP and atypical control. There were also significant differences found between all groups, except for ASD and seizures for the motor subdomain. Lastly, significant differences were found in the cognitive subdomain between the atypical control and the neurodevelopmental groups.

Previous studies have indicated that children with ASD perform lower on developmental domains, including daily living skills, socialization, and communication, with differences almost 2 standard deviations below the mean (Goyla & McIntyre, 2018; Klin et al., 2007; Jasmin et al., 2009). Jasmin and colleagues (2009) found that children with ASD performed low on personal and daily living skills subdomains on the VABS-2. Compared to the atypical developing control

group, the ASD group performed as expected, as one would expect significant differences in the adaptive, personal-social, and communication subdomains. Further, the significant difference between ASD and atypical control was expected for the motor domain. Previous studies have indicated significant delays in motor abilities in children with ASD (Jasmin et al., 2009; Lloyd et al., 2013). Jasmin and colleagues (2009) found that 57% of children with ASD had an overall motor delay, with 63% having gross motor delays and 53% having fine motor delays. Given that ID occurs in 40% of individuals with ASD (Arvio & Sillanpaa, 2003), the ASD group was expected to perform lower than the atypical control group for the cognitive subdomain, even if both groups were blocked for ID, as some may not have been diagnosed yet or their cognitive impairments do not meet the requirements for a diagnosis.

Significant differences were found between the ASD and seizure group on the personal-social and communication subdomains. Previous studies have found that children with ASD score lower than atypical controls and children with seizures score lower than children without seizures on the BDI-2 total developmental quotient and all developmental subdomains (Matson et al., 2010). However, Milovanovic and colleagues (2019) did not find significant differences between the seizure and control group in communication, daily living skills, socialization, or adaptive domains, but did find a significant difference in the motor domain. This difference could be the difference in measures used, as Milovanovic and colleagues (2019) used the Vineland Adaptive Behavior Scales, Second Edition (VABS-II; Sparrow et al., 2005), while the Matson and colleague (2010) and current study used the BDI-2. Regarding cognitive functioning, adults with seizures, ages 16 to 55, were found to have a mean full-scale IQ between 86.71 and 88.30, depending on the type of seizure, with the left-temporal complex partial seizure performing the worst and the right-temporal complex partial seizure performing the best

(Giordani et al., 1993). However, children with ASD were at the 26th percentile for the FSIQ on the WISC-III, compared to the 70th percentile for controls; however, the authors note that the WISC-III underestimates abilities in individuals with ASD, as the Raven's Progressive Matrices (Raven & Court, 1938) were significantly different at the 56th percentile, compared to the controls which did not differ significantly (Dawson et al., 2007). Therefore, the current finding is not surprising, as the BDI-2 may better capture abilities of individuals on the spectrum.

On the other hand, significant differences were found between the ASD and CP groups for the personal-social, communication, and motor subdomains. This finding followed expectations, as the primary deficits in ASD are related to personal-social and communication, while the primary deficit in CP is related to motor difficulties. In addition, previous studies have shown that children with CP score similarly on communication and social domains compared to typically developing peers (Tan et al., 2019). Regarding the cognitive subdomain, Türkoğlu and colleagues (2017) found that only 26.2% of the sample of 107 children with CP scored within the norm on standardized intelligence testing. However, similar to the Dawson and colleagues (2007) study, which concluded intelligence testing in individuals with ASD underestimates abilities, a review by Yin Foo and colleagues (2013) found that intelligence testing in children with CP is also unreliable, especially with motor, communication, and visual impairments. Due to the underestimation of cognitive functioning in both groups, it is not surprising there was not a significant difference found between the two groups.

The current study found the seizure group showed significant differences from the atypical control group on all subdomains except for communication. In a previous study by Matson and colleagues (1999), they found significant differences between individuals with seizures compared to controls on domains for socialization, communication, and daily living

skills. The current study did not find a significant difference for communication, which could be due to the fact the population in the Matson and colleague study (1999) was older (mean age 37.85 years) and had comorbid ID. Clary and colleagues (2010) found that children with seizures experience deficits in daily living skills, socialization, and communication. The deficits in adaptive functioning and socialization support the previous research indicating daily living skill deficits. However, the communication was not found to be a significant difference, which could be in part due to the age differences in the samples and the use of different measures between the studies. In addition, a study by Pastor and colleagues (2015) found that a greater percentage of individuals with epilepsy, compared to those without in the National Survey of Children with Special Health Care Needs (CSHCN), had motor difficulties, such as walking and coordination and using their hands, self-care, learning, and communication. Further, Neyens and colleagues (1999) found that children with seizures scored lower IQ scores than controls and showed significantly less growth in IQ scores over a 1.5-year follow-up, and thus, supports the finding of this study in which the cognitive domain was significantly different.

The CP group also had significant differences from the atypical control group on all subdomains except for communication. Tan and colleagues (2020) found that individuals with CP scored similar to peers on social and communication domains of the VABS. However, this study investigated individuals within a wider age range (1 to 20 years), which could have impacted results, as Voorman and colleagues (2019) found that deficits in social functioning and communication increase over time, and therefore a significant difference within the communication domain might not be as apparent in infants and toddlers seen in this study. On the other hand, another study found communication and social functioning are lower in children with CP than typically developing peers (Voorman et al., 2010). The difference in

communication findings could be due to the differences in populations, as the current study involves infants and toddlers in Louisiana, whereas the Voorman and colleagues (2010) study, the children with CP are sampled from the Netherlands, while their typical control group was sampled from the US, which could lead to inflated differences in communication. Regarding motor skills, previous research has found significant deficits in individuals with CP. Previous research suggests a positive correlation between motor ability and cognitive abilities (Vohr et al., 2005; Enkelaar et al., 2018). In a sample of 78 children with CP, 51 performed at the same level for mental and motor functioning, for the remaining 27 children, they were more delayed in motor functioning (Enkelaar et al., 2018). These deficits are similar to the deficits found in the current study, with significant differences in the motor and cognitive domains compared to atypical developing peers. Further, studies have implicated a relationship between motor and daily living skills, where daily living was related to the severity of mobility restrictions (Ostensjo et al., 2003), and thus would suggest a deficit in the adaptive domain as well in the CP group. As previously discussed, studies have also implicated deficits in daily living skills in children with seizures, which would suggest a lower score in the adaptive domain. Therefore, a significant difference between the CP and seizure group would not be expected for the adaptive domain in the current study.

Lastly, the seizure group significantly differed from the CP group only on the motor domain. Although individuals with seizures experience difficulties with motor, it is not to the extent one would expect for an individual with CP, and therefore this finding is expected. In addition, given that motor ability is associated with adaptive skills in children with CP (Ostensjo et al., 2003), one would expect the CP group to score low on the adaptive domain. However, given the adaptive deficits in seizure groups, the non-significant difference between the CP and

seizure group is not surprising. Studies by Voorman and colleagues (2010) and Berg and colleagues (2004) found similar results in CP and epilepsy populations, respectively, for social and communication domains, suggesting no significant difference, which aligns with the current findings in these domains. A review by Fennell and Dikel (2001) note that overall, 50 to 70% of individuals with CP have IQ scores below 69; however, this rate varies by level of CP. Further, they cited articles that found correlations between motor difficulties and IQ in children with spastic quadriparesis and found that IQ was underestimated in children with language and motor deficits.

Overall, there was a general trend for ASD group to score lower on the subdomains across the board, except for the motor domain, followed in general by CP, seizures, and lastly the control group. Therefore, it is expected that the scores for the total DQ would be significantly different, and follow the same trend, as the total DQ is a combination of the subdomains. Similarly, Burns and Matson (2018) investigated the total DQ in four groups: atypical developing, atypical and seizures, ASD, and ASD and seizures. They found that the ASD/seizure group to score the lowest, followed by the ASD group, seizure group, and lastly the atypical group. Additionally, Matson and colleagues (2010) found that the ASD with seizure group scored the lowest on the total DQ, followed by ASD, seizure, and lastly the atypical group. The current study supports these previous findings, such that the ASD group was expected to perform lower than the seizure group, and both perform lower than the atypical control group. Regarding the CP group, previous studies have suggested individuals with CP score similarly to typically developing peers and peers with epilepsy on communication and social domains (Tan et al., 2019; Voorman et al., 2010; Berg et al., 2004). Further, individuals with CP, similar to those with seizures, were found to score low on intelligence testing, although this is likely an

underestimate of their cognitive abilities (Türkoğlu et al., 2017; Dawson et al., 2007; Yin Foo et al., 2013; Fennel & Dikel, 2001). However, given the motor deficits in individuals with CP, one would expect this domain would pull down the total DQ score lower than the seizure group.

The current study found significant differences between the ASD and atypical and CP and atypical groups for age. When controlling for age, a significant difference was found between the ASD and seizure group ($p = .003$) for the motor subdomain. In addition, a significant difference was also found when controlling for gender ($p = .003$), compared to the original non-significant finding ($p = .022$), although it was approaching significance. In addition, while controlling for age, a new significant difference was found between the ASD and CP group in the cognitive domain ($p = .002$), compared to the original non-significant finding ($p = .092$). In the original analyses, developmental domains were investigated with consideration of diagnostic group, age, and gender. When controlling for age or gender, this could remove some covariance and increase size effects and reveal significant differences not previously seen.

Lastly, when controlling for gender, the ASD and seizure group no longer had a significant difference for the total DQ ($p = .013$), compared to the original significant finding ($p < .0001$). This could be explained by the fact the two disorders have different gender ratios for diagnoses, such that ASD is 4:1 male to female, while seizures is close to 1:1. Therefore, when controlling for gender, the covariance due to gender could remove a significant difference between the groups. However, controlling for gender may remove meaningful variance between the two groups, given the unequal gender ratios are inherent in the two neurodevelopmental disorders.

By blocking the groups with individuals with GDD, the cognitive group would have been the most impacted if this study had not blocked with GDD, given that GDD impacts cognitive

functioning. Shevell and colleagues (2005) found that preschoolers with GDD scored significantly lower on the total DQ and all BDI-2 domains except for communication, and all domains of the VABS, compared to peers with developmental language impairment. Another study found that individuals with ID have difficulties with social communication (Smith et al., 2020) and motor skills (Vuijk et al., 2010; Rintala & Loovis, 2013). Comorbid ID and ASD has been shown to decrease adaptive domains such as communication, socialization, and daily living skills, as individuals with ASD scored higher than those with ASD/borderline ID, and ASD/Mild ID, with individuals with ASD/Moderate ID showed the greatest impairment (Matthews et al., 2015). In addition, comorbid ID in individuals with CP has been implicated in motor deficits (Reid et al., 2018). The study by van Ool and colleagues (2019) found that in 1/3 of their sample of adults with comorbid ID and epilepsy there was a discrepancy in their ID profile, due to social deficits. The interaction between ID and the respective neurodevelopmental groups could have lowered the mean developmental scores, compared to neurodevelopmental groups without participants with comorbid ID.

However, the percentage of individuals with GDD in this study was much lower than expected. This could be due to the process of data collection, such that many of the participants are entering EarlySteps and have not yet received a comprehensive psychological assessment, and therefore the number of children with diagnoses of GDD is lower than in the general population or in older children. In addition, a statistically significant difference was found for age between the ASD and atypical control group and between the CP and atypical control group. Further, there were significant differences found for gender between the groups. This can be explained by the inflated ratio of males diagnosed with ASD expected, as the national ratio is 4:1

(Maenner et al., 2020), compared to more equivalent ratios found in the other neurodevelopmental disorders.

Given this study's significant findings, there are both short term and future implications. For instance, EarlySteps providers may find these results applicable to therapy (e.g., speech therapy, occupational therapy, special instruction), as they may understand a child with ASD may perform lower than atypical developing peers in most domains and thus may encourage providers to change their approach or alter their expectations to best help the induvial. Further, f they have a client with ASD, they may plan for extra time for various treatment goals, understanding that they perform lower than the other neurodevelopmental groups in the cognitive domain and may need extra time to fully grasp concepts than other clients. Future studies may consider investigating further differences between these groups with and without GDD or ID. In addition, future studies may consider parsing out developmental profiles for these neurodevelopmental disorders or see how these developmental domains change over time.

The current study is not, however, without limitations. The study relied heavily on parent report on the BISCUIT-Part 1 demographic form for parent report of history of seizures and a diagnosis of CP. In addition, due to this information being collected via parent report and the nature of the measure, further information regarding types of seizures, number of seizures, and when the last seizure occurred is not available. Similar information is missing regarding the participants with CP, specifically the type and level of CP. Moreover, ASD diagnoses were not confirmed via comprehensive diagnostic assessments. The current findings should be interpreted with this in mind.

The groups in this study had an equal number of participants with comorbid GDD, which attempted to add to the generalizability of the study. However, inclusion of GDD is also a

limitation, as the differences between groups could be in part due to how GDD interacts with the neurodevelopmental groups. In addition, the groups significantly differed on demographic features such as gender and age, which may negatively affect generalizability of these results. Lastly, the sample was recruited from Louisiana's statewide early intervention program, EarlySteps, and thus may not be representative of other populations.

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Vita

Megan Callahan, born in Schaumburg, Illinois, received her Bachelor of Science in neuroscience with minors in psychology and theological studies from Saint Louis University in St. Louis, Missouri. Megan is currently a third-year graduate student under the supervision of Johnny L. Matson, Ph.D. Her clinical and research interests include the identification and treatment autism spectrum disorder (ASD) through the lifespan. She plans to receive her Masters in May 2022.