# Neurodevelopmental Disorders:
# Exploring how Nature & Nurture Interact to Display Various Disorders

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## Neurodevelopmental Disorders

Neurodevelopmental disorders are some of the most complex forms of neurodiversity in children. This phenomenon originates from disabilities and abnormalities directly related to the body's nervous system and brain. Neurodevelopmental disorders generally have a profound effect on an individual's ability to process language and speech, perform motor skills, remember/learn information, and often cause associated problem behaviors (Neurodevelopmental disorders, 2015). Of course, depending on the diagnosed disorder itself, symptoms and causes will vary from case to case. Given the symptoms associated with neurodevelopmental disorders, there are subsequent behavioral and intellectual specific problems that commonly arise. There are some variations of developmental disorders that have a profound impact on a child's intelligence and some that have more intrusive behaviors that take priority.

The overall prevalence of neurodevelopmental disorders in children has risen remarkably over the last few decades in the United States. Just between 2009 and 2017, the National Health Interview Survey reported a 9.5% increase in various developmental disabilities in children ages 3-18 (Durkin, 2019). This could be due to a drastic increased understanding of diagnostic criteria for the disorders or a slightly lessened societal stigma around receiving treatment for mental health issues in general. School teachers and other educators in the United States are credited for a greater awareness of behavioral symptoms involved with neurodiverse students, which in turn pushes for further investigation into a child's cognitive functioning. Additionally, it is often found that neurodevelopmental disorders as a whole will also evolve as a child ages. Some kids simply "grow out" of certain neurological anomalies through development, causing this prevalence percentage to waver depending on demographics.

**Introducing Nature & Nurture**

With this recent increase in overall awareness for neurodevelopmental disorders, it is essential to have a comprehensive understanding of how these disorders originate genetically, environmentally, and socially. The long debated psychological theory of nature vs nurture provides a perfect explanation for how these two individual concepts work as one cohesive unit throughout the development of *any* child. More specifically, this theory is essential when investigating the roots of various neurodevelopmental disorders in children as well.

First, the nature side of this argument focuses primarily on the role that genetics and psychobiology play in the presentation of different disorders. There are few neurodevelopmental disorders that can be traced back to one specific set of genes; instead, there is usually a very complex array of contributing factors.

Most children born with an immature neurological system will exhibit inherently noticeable symptoms of a distinct disorder from birth. Poor head control, flexed limbs, inability to fixate the eyes on objects, and unresponsiveness to sound are just a few indicators of a potential neurodevelopmental disorder as a result of biological abnormalities (World Health Organization, 2011). It is clear in these scenarios that there are no environmental or “nurturing” contributors to the newborn’s condition. When a child is born with physical symptoms indicative of a neurological problem, genetics and abnormal brain structure are investigated to establish a specific disorder.

Studies around temperament in babies have been helpful in determining genetic roles in child behavior. In fact, specific qualities, such as dependency, attachment, and security are all considered heritable aspects of personality that are derived biologically (Roisman, 2008). It is important to note that there is a difference between heritability and direct genetic influence.

Heritability alone measures the importance of genetics toward a singular trait. Though, in this instance “nature” can cover *any* predetermined biological influence on our human experience – potentially involving premature birth, low birthweight, pregnancy complications, etc.

Next, for the nurture side of this theory, environmental risk factors are first considered; the most common being maternal substance abuse, lower socioeconomic status, and exposure to atmospheric contaminants. For example, The National Toxicology Program has developed numerous tests concluding that prenatal or childhood exposure to lead can have a large impact on cognitive function, intelligence, and academic performance. The NTP also discovered a significant link between lead exposure, neurodevelopmental problems, and various conduct disorders (Neurodevelopmental disorders, 2015). The growing brain in-utero is incredibly vulnerable to the negative effects of any environmental pollutants. Starting right after conception, the critical process of neuron growth begins and can be easily disrupted by even the slightest exposure to unnatural elements.

Another influential aspect of nurture is how a child is socialized by their families and other surrounding community members. The manner in which a child is raised, where the child is living, traumas they endure, presence of family members, cultural norms, etc. are going to leave a life-long impression on their sense of self and the world around them. Childhood experiences will assist in establishing an individual’s personality, coping mechanisms, behaviors, performance, social relationships, and much more as they age – most of which cannot be genetically determined through nature.

As previously mentioned, the concept of both nature and nurture work together as a child develops. Sibling and twin studies specifically have been utilized for decades to determine how different genetic combinations effect the way children shape their individual environments. In

1994, Dr. Robert Plomin and his team at Pennsylvania State University conducted a large quantitative study of over 700 sibling pairs in which they determined a significant genetic heritability around environmental interaction. In other words, Plomin's study confirmed that children will interact dynamically in social settings, with family, and with their surrounding environment based heavily on their genetic makeup. It is interesting to note that although nature and nurture evolve as independent entities, they will always interact and effect one another simultaneously.

In terms of the presentation of neurodevelopmental disorders in children, studies have shown that almost all psychological phenotypes are naturally heritable. Therefore, it is the detectable, environmental nurturing that is responsible for making biological siblings and twins unique (Roisman, 2008). This interplay between nature and nurture in regard to the development of neurodiversity in kids can lead to a more accurate and comprehensive understanding of the origination and presentation of the disorders themselves. The concept of nature and nurture, in combination with other psychological theories, will be applied to examine how Autism Spectrum Disorder, Hemimegaloencephaly, Down Syndrome, and Attention Deficit Hyperactivity Disorder are conveyed in children as a whole.

## Autism Spectrum Disorder (ASD)

Autism Spectrum Disorder is neurodevelopmental disability characterized by social, communicative, and behavioral problems. Autism is considered a spectrum disorder in reference to the wide range in symptom severity, especially for children. Diagnosing and describing the symptoms for children diagnosed with ASD can be a difficult task since they can vary so drastically. The most identifiable social symptoms of a child with ASD include an overall lack in interest in others, trouble expressing emotion, and avoidance of physical contact.

Communication impairments can range from an entirely nonverbal child, to a child who is very articulate with their words but doesn't vocalize them in a socially acceptable manner (Neurodevelopmental disorders, 2015). Behavioral problems can also range from narrowed/restrictive interest in certain subjects, to repetitive movements like flapping, or even self-injurious habits.

Intrusive behaviors and limited intellectual functioning are all potential identifiers for a child with Autism, but social interaction is arguably the most noticeable. Avoidance, inability to recognize social cues, and apparent disinterest in others are just a few social barriers in ASD. There are many myths surrounding Autistic children's limited desire for friends or even interaction, but in reality there is a gap preventing them from communicating their desires with others effectively. This can relate back to the Theory of Mind, which is considered to be the foundation to all social interactions. Theory of Mind is defined as the human ability to attribute mental states to others and ourselves, essentially allowing us to predict and interpret behavior by other people (Ruhl, 2020). Children and even adults with Autism are often characterized by an impaired Theory of Mind as a result of poor social skills during the diagnostic process. Children specifically display extreme difficulty with understanding sarcasm, lying, opinions of others, rationalizing others' actions, and plenty of other navigational tools. Given that Autism Spectrum Disorder's key symptoms include social complications, limited development for Theory of Mind often positively correlates.

Given the varying nature of associated symptoms with Autism, there are numerous sub disorders falling under the spectrum. Asperger's Syndrome is considered a less severe and intrusive form of ASD that emphasizes social peculiarities. Children with Asperger's will exhibit inability to socialize due to limited facial expressions, unusual mannerisms, and extreme

sensitivity to sensory stimuli. Pervasive Developmental Disorder- not otherwise specific (PDD-NOS) is another variation of Autism characterized by delays in overall cognitive development. This includes limited verbal and non-verbal communication, narrow affect, and restrictive behaviors as a result. Classic Autism is the final sub disorder associated with ASD and its recognized as the most severe form. Children with Classic Autism will have the most noticeable troubles with auditory speech, destructive behaviors, and overall social interaction. ASD is an extremely unique neurodevelopmental disorder in the sense that no two cases are identical – each diagnosed individual experiences an unparalleled set of varying symptoms falling somewhere within that wide spectrum.

**The Nature of ASD**

In terms of nature, there has been no significant findings from any research pointing to one, specific biological cause for Autism Spectrum Disorder. This is largely due to the fact that the disorder is diagnosed behaviorally in terms of typical cognitive and social development. There have been countless studies determining genetic and congenital links to Autistic diagnoses. For instance, there are identifiable “de novo” mutations found throughout the central nervous system of ASD children. *De novo* mutations occur when there is a congenital abnormality without the child inheriting it from the mother or father. There is a majority of Autism diagnoses originating from genetic mutations, rather than inheriting ASD related traits from a parent.

Even though there isn’t one specific known cause for Autism Spectrum Disorder, there remains an extensive push to determine the indicators and biomarkers for related symptoms. Biomarkers don’t always need to be understood through genetics alone, “A biomarker candidate can be defined as such if it is a biological variable associated with the “disease” condition and

measurable directly in a given patient or in the patient's biomaterials through sensitive and reliable quantitative procedures" (Kiln, 2018). Therefore, a better understanding of the prenatal origination of this condition can assist researchers in developing biosample tests, with blood or urine for example, or stricter measurements of neuropsychological performance. Not only would this allow for earlier detection and more effective treatment, but it would also create a more consistently accurate diagnostic process.

Luckily, there has been a lot of recent progress with genomic studies for Autism and its biological differences in comparison to a typically developing child. For example, the FMR1 gene is often associated with Fragile X syndrome and recent research shows a strong correlation to Autism as well. These mutations in the FMR1 gene occur most often when there is an expansion of repeat sequences on the X chromosome, mostly affecting boys as a result. This finding could attest to why boys are diagnosed with ASD more often than girls, since a majority of this biological research occurs on male subjects. There is, and always has been, a major discrepancy between males and females within the Autism community – suggesting a significant difference between the biological structure of their brains (*Sex bias and the genetics of autism*, 2020).

The cerebral cortex is one of the most influential part of the brain in terms of autistic symptoms. Here, there are about 20 billion neurons that are constantly communicating electrochemically. 100 billion total neurons must function and form the perfect circuits throughout the entire brain before a child is born, so it isn't necessarily surprising that there are miscommunications among some of those connections. The Amygdala is another commonly altered brain structure for Autistic children, responsible for an individual's stress responses, like fight or flight. Studies have shown that the Amygdala grows too large and too quickly for

children with ASD, causing increased impulsive anxiety. Common anxious symptoms in Autistic children include the desire for rigid structure and consistent stimming. The Amygdala also loses neurons and spines as children with ASD age which can cause various issues with intellect and language development (*Why is studying the brain important for understanding Autism?, 2019).* A comprehensive understanding about the nature of Autism Spectrum Disorder points to how biological makeup can affect environmental interactions.

**Nurturing ASD Symptoms**

Nurture plays just as important of a role as genetic predispositions. Raising any child is never a small feat, but a child with Autism may present new or worsening symptoms as they get older due to their surroundings alone. There are other, more socially understood nurturing factors contributing to Autism, such as prenatal exposure to toxins, parental age, maternal obesity, and auto-immune disorders - all of which can play a significant role in Autism progression. But, it is important to emphasize the other environmental risk factors that can contribute to symptoms *after* birth.

Severe trauma or neglect are one contributing factor to trigger “quasi-autistic” symptoms in children. This term refers to indistinguishable, clinical differences in neglected children – meaning that there are no real medical indicators in their presentation compared to the typical child. But, traumas that cause any kind of experiential deprivation in young children often correlate with ASD related behaviors and tendencies (Strathearn, 2009). In fact, some of the most intrusive sensory abnormalities associated with Autism can result from specific environmental exposures. Both auditory and tactile hypersensitivities were the most common among a quantitative study conducted on over 4,000 eight-year-olds – both with and without ASD. Jussila and their team were able to conclude that settings like noisy environments or close

quartered rooms are accurate predictors or ASD related behaviors (2019). Observing an infant's behavioral reactions to certain environmental stimuli can almost always indicate Autistic tendencies.

**Combined Efforts from Nature & Nurture**

Countless studies and researchers have been able to prove that Autism Spectrum Disorder has extremely strong genetic links along with apparent environmental influences. It is extremely rare to have a case arise solely off of one contributor over another. Of course, there will be cases in which congenital brain deformities or an unfortunate prenatal exposure to alcohol will induce Autistic symptoms in a child. But more often than not, nature and nurture interact as a cohesive unit to present ASD. In his exploratory article regarding the interplay of nature and nurture in Autism, Lane Strathearn summarizes this idea, stating that even though science provides us with a "…genetically based "broad autism phenotype", it is also possible… that "the patient, endowed with an innate disability to relate to people, is further influenced adversely by the parents…" (2009).

One specific, quantitative study conducted on adults and adolescents with ASD concluded that there is a significant contribution from both genetics and socialization for overall cognitive flexibility specifically, **"**…our results suggest variable findings of impaired cognitive flexibility between children, adolescents, and adults. Investigating impairment in cognitive flexibility across the lifespan in persons with ASD has important clinical ramifications in terms of understanding the repetitive and restricted behaviour that is the hallmark of ASD" (Leung, 2014). Leung and her team performed various cognitive tests on Autistic individuals that not only analyzed the correlation between a lack in cognitive resilience and restrictive behavioral symptoms, but also suggested an equal contribution from both nature and nurture to cause said

behaviors. Certain tendencies, such as ticks and repetitive rocking/flapping, are often considered congenital. While other behaviors, like aggression in the presence of overwhelming auditory stimuli, or tantrums when daily routine is altered, are often considered a result of their environment. As Leung implies in her article, the cognitive inflexibility experienced by children with ASD result in symptomatic behaviors derived from the combined reciprocity of both nature *and* nurture (2014).

## Hemimegaloencephaly (HME)

The term Megalocephaly refers to a condition in which a child's entire brain is abnormally large and heavy for their age. This concept - combined with the prefix hemi meaning "one half"- constitutes Hemimegaloencephaly where only *one* half of the brain is bigger than the other. Hemimegaloencephaly, or HME, is an extremely rare cortical malformation causing severe developmental delay and epileptic seizures. The structural differences on opposing hemispheres disrupt neural communication between both halves of the brain, altering cognitive development and behavior.

The main characterizing symptom of HME is epileptic seizures. Abnormally enlarged brain tissue as a result of structural inconsistencies can generate electrical abnormalities beginning as early as an embryo. Most cases of HME develop shortly after conception, where seizures in-utero lead to abnormal brain growth. Seizures can even exceed over fifty instances each day and rarely decline in their severity throughout the child's development (Rare disease database, 2012). HME seizures can cause a temporary distortion of reality, increased staring, uncontrollable muscle movements, loss of consciousness and/or trouble with sleep – all of which are incredibly invasive for a child's daily life, never mind anxiety leading up to episodes. Other physical indicators of HME in children can be found during medical examinations; doctors have

reported larger head circumference or asymmetrical head shape. A child with HME could also display motor deficits, like poor coordination or trouble writing, on the side opposite of the cortical malformation (Rare disease database, 2012). Doctors can usually suspect HME after a physical examination and MRI that examines brain structure and size.

Hemimegaloencephaly has numerous neurocutaneous comorbidities given the nature of the brain's growth and development in the womb. Neurocutaneous disorders affect the entire central nervous system, along with the body's organs, skin, and bones. Some of these disorders include proteus syndrome, Klippel Trenauanay Weber Syndrome, and Neurofibromatosis (Wu, 2014). Proteus syndrome causes asymmetric overgrowth of skin, bones, lymphatic vessels and other tissues throughout the body. Children with proteus syndrome often have scoliosis, rough or raised skin, and/or longer limbs on one side of the body all attributed to uneven brain structure. Klippel Trenauanay Weber Syndrome is similar to Proteus syndrome in the sense that soft tissues and lymphatic vessels are overgrown, but Weber syndrome diagnoses must include three specific indicators: a red birthmark, also called a port-wine stain, tissue/bone overgrowth, and vein malformation. Children with Weber syndrome tend to have more issues with blood clots and joint dislocation at birth. Neurofibromatosis is a genetic condition that disrupts nerve cell formation, causing tumors on nerves throughout the body. Children with Neurofibromatosis often struggle with bone deformities, skin dyspigmentation, shorter stature, headaches, hearing loss, and altered equilibrium. These three disorders, along with HME, are all associated with cognitive development which also results in severe learning disabilities. Children with HME and any of its comorbidities are predicted to struggle immensely in school and are often noticeably behind in terms of social skills, behaviors, and intellect – compared to typical peers.

A recent study conducted by Lauren Libero and her team investigated the prevalence of HME and related abnormal brain growth with Autism Spectrum Disorder. As previously discussed, recurring findings have proven a positive correlation between disproportionate brain size and Autistic symptoms in children (Chawarska, 2011). Therefore, Libero aimed to determine brain to body proportions, like HME or Megalocephaly, and its relation to long-lasting restrictive behaviors and intrusive symptoms by conducting a longitudinal study on over 180 male children. Their research concluded that there is a distinct pattern of abnormal acceleration in brain growth until around five years of age, causing an increase in Total Cerebral Volume which directly inhibits cognitive function (Libero, 2016). Heavier brain weight, increased cerebral volume, large head circumference, and brain asymmetry can delay overall intellectual development in early childhood – often physically presenting via Autism.

**The Nature of HME**

Since this neurodevelopmental disorder is so rare, there is little research confirming a confident cause. However, Hemimegaloencephaly (HME) has been reported in significant numbers for children, suggesting that the origination is largely biological. First, it essential to understand physical neural cell structure and development. Neurons in the enlarged half of the brain are typically malformed and migrate abnormally as a result. Incorrect cell signaling and communication from a genetic abnormality leads to a discrepancy between the affected and unaffected hemispheres, "If two cell lineages arise from the neural crest progenitor cell line, one exhibiting normal cellular physiology and the other abnormal cellular physiology, then different migration patterns could be observed" (Wu, 2014).

Another biological indicator of HME is a mutation in the "dynein cytoplasmic 1 heavy chain 1" or "dync1h1" gene. This gene provides the instructions for the formation of protein

groups called dynein. Dynein is found within the cytoplasm of cells throughout the body and binds itself to another protein complex called dynactin. This dynein-dynactin pair then moves various materials, such as proteins, along a track of microtubules around the body. The pair also helps position cell compartments, moves structures within the cell, and most importantly allows neurons to communicate through synaptic vesicles that contain chemical messengers. Without the effective intercommunication from both dynein and dynactin, neuronal nuclei would not be able to receive any chemical message from the rest of the body (DYNC1H1 gene, nd.). As a result, mutations in the dync1h1 gene are often responsible for more severe intellectual disabilities among children as neurons do not communicate as effectively between one another. This insufficient transmission of chemical information can also delay brain development and growth asymmetrically, causing conditions like HME.

**Nurturing HME Symptoms**

Research on the nurturing aspects of HME is extremely limited. Therefore, it is unlikely that there are any in-utero or environmental conditions attributed to asymmetrical brain growth. Instead, it is important to understand environmental interactions for a child with HME. One extremely influential factor for HME symptom severity is persistence of epileptic seizures. The quantity and severity of seizures as a result of abnormal brain development in HME can be triggered by certain environmental elements, such as flashing lights and stress, "…prolonged exposure to pharmacoresistant epilepsy can impair cognition. In a cohort study of 198 children, pharmacoresistant epilepsy was associated with lower performance on cognitive tests" (Wu, 2014). In other words, a child's given surroundings are not directly causing HME itself, but the environment can and will intensify epileptic episodes. Increased seizures have been proven to disrupt cognitive processing overall, like information comprehension, problem-solving,

imagination, judgement, and planning, which can also carry over into the child's ability to socialize.

Social interaction with HME is similar to that of Autism Spectrum Disorder. Not only will social competence range among children depending on the intensity of their brain malformations and seizure consistency, but poor Theory of Mind is also probable. When cognitive functioning is impaired, a child's innate ability to view life from another perspective is impacted. In regard to theory of mind, children with HME are going to struggle to read the mental state of others, understand other's desires/intentions, or have difficulty with genuine interaction in a non-preferred environment – all of which are similar to an Autistic child's interpersonal struggles. One notable difference is that children with HME tend to have a shorter temper, often reacting exclusively out of anger when things don't follow a plan they had envisioned.

**Combined Efforts from Nature & Nurture**

In the case of Hemimegaloencephaly, nature and nurture interact in crucial ways – not necessarily towards the origination of the disorder, but for symptom severity experienced by the child. HME begins with genetic abnormalities disrupting brain development and growth, while the environment and social surroundings can influence which symptoms present most intensely. Proper education is a great example of another environmental influence that can work cohesively with congenital brain malformations to bridge the gap between disrupted cognition. Children with HME are undoubtedly going to struggle in school, whether that means focusing in the classroom, interacting with peers, or receiving passing grades. A majority of children with any neural abnormality are going to be provided with an Individualized Education Program (IEP) to ensure that their inborn condition will not get in the way of learning. Nature and nurture are both

taken into consideration throughout the child's academic journey to provide the least intrusive learning environments and most ideal to path to success.

## Down Syndrome (DS)

Down Syndrome (DS) is one of the most well-known neurodevelopmental disorders across modern societies. There has been extensive research conducted in regard to almost every aspect of the disorder, with recent discoveries making distinctions between three variant types of DS. Trisomy 21 is the most common type of Down Syndrome in which every cell throughout the body has the extra chromosomal copy. Translocation Down Syndrome is similar to Trisomy 21, but the extra chromosomal copy is attached to another chromosome, rather than being on its own. Lastly, Mosaic Down Syndrome is the rarest form, where only a small portion of the body's cells have three copies of chromosome 21, instead of two (Pathak, 2020).

Down Syndrome individuals typically experience universal symptoms, regardless of the variant of the disorder they may have. DS is often identifiable by its physical characteristics first, such as a flattened skull and face, slanted eyes, shorter neck, small stature, a protruding tongue, and poor muscle tone. Some cognitive symptoms include difficulty learning/processing information, poor judgement, impulsivity, short attention span, and poor communication skills. Given that physical indicators of DS are present at birth, it is easier to initiate early interventions, like speech therapies, to promote timely development. Early identification also can assist in preventing other comorbidities from becoming too intrusive. Down Syndrome is associated with a plethora of co-disorders, "…health issues common in Down syndrome also are tied to various aspects of functioning, including the effects of hearing problems on language development, of heart surgeries on cognitive functioning, of the size and thickness of the tongue on articulation, and of sleep problems on psychological functioning" (Hodapp & Fidler, 2021). Down Syndrome

is also commonly comorbid with Fragile X Syndrome. The disorder can be detected through blood or DNA testing, given that it originates from a protein imbalance needed for typical brain development. Therefore, Fragile X Syndrome results in various cognitive impairments and delays, such as limited intellect, unusual behavioral patterns, and reaching developmental milestones much later than peers.

Further research has been conducted to establish a potential link between Down Syndrome and psychological abnormalities as well. Steven Reiss (1994) of Ohio State University designed a study consisting of 583 children and adolescents with "mental retardation" to screen them for a dual-diagnosis for DS and psychopathology. In this case, psychopathology was referring to any condition causing anxiety, depression, paranoia, dependent personality traits, avoidant behavior, or thought disorders. Reiss and his team were able to develop a reliable test to evaluate conduct issues in children with Down Syndrome that could point towards an additional psychopathological diagnosis. They found this test accurately represented behavioral concerns as a result of psychological distress in children with DS (Reiss & Valenti, 1994). This was an incredibly influential discovery given that the "Reiss screening" is still being used today in order to provide more accurate diagnoses of psychopathological comorbidities, which can eventually lead to more effective treatment interventions.

**Nature & Nurture in DS**

As mentioned above, all three variants or types of Down Syndrome involve an extra copy chromosome 21. The human cell typically has 23 total pairs of chromosomes, with one chromosome coming from the mother and the adjunct coming from the father. This abnormal duplication occurs in-utero as a result of abnormal cell division. Essentially, the cells are left

with extra genetic material, which is what contributes to the positive symptoms and unique physical characteristics.

There are certain, proven risk factors that can increase the likelihood of a baby developing an extra chromosomal copy. Older parents, specifically mothers over the age of 30, are at the highest risk of giving birth to DS children. Chronologically older eggs hold a greater risk of improper or abnormal cell division. In fact, studies show that up to 12% of all-natural births by mothers over the age of 40 resulted in a baby with Down Syndrome (Hodapp & Fidler, 2021). There are also certain genetic traits that can be passed down for Translocation Down Syndrome specifically. Similarly, if parents already have one child with DS, the odds of having another child born with the disorder is much higher. Down Syndrome has an incredibly high genetic inheritance rate, therefore understanding any potential risks as a parent is extremely important before conceiving. The biological origination of this disorder is relatively straightforward, so it is the role a child's environment that will influence their symptomatic behaviors and progressive development more directly.

Down Syndrome consistently impacts the lives of children through various physical and developmental delays. Children born with DS will experience certain developmental milestones, such as walking and talking, significantly later than typical children. Though, this does not necessarily mean that those goals will never be met. In fact, children with Down Syndrome tend to meet a majority of developmental criteria, just at a slower rate.

A quantitative study performed in Cape Town, South Africa compiled a series of tests to determine what influences the rate at which children with Down Syndrome are developing in comparison to other DS children of different races. They hypothesized that ethnicity was a major contributor to the quality of education being provided in certain geographical areas, which is

directly affecting their developmental progression. They followed a total of 50 male and female South African students with Down Syndrome attending five different elementary schools in Southern Africa. They methodically compared their cognitive development in reference to their schooling as a result of race. The study concluded that black DS children, coming from a lower socio-economic background, were scoring lower on intelligence tests and speech subtests than their white counterparts, "…much of the developmental delay may not be innate, but rather stem from the fact that people with Down syndrome receive inferior education, are 19ocialized into an acceptance of subordination and are saddled with low expectations of their abilities" (Molteno & Ahmed, 1997). Down Syndrome is an entirely congenital disorder, therefore the quality of education and social exposure that they receive within this developmental period is crucial. The research provided by Molteno and Ahmed further proves that nature poses children with this mutative disorder, but nurture will establish how the individual interacts with it and potentially overcomes its challenges.

**Attention Deficit Hyperactivity Disorder (ADHD)**

Attention Deficit Hyperactivity Disorder, or ADHD, is one of the most common neurodevelopmental disorders in children between the ages of 3 and 17 years. ADHD is a childhood-onset disorder or inattention, hyperactivity, and impulsive behaviors (Faraone, 2000). Children with ADHD typically have trouble sleeping, focusing their attention without distraction, remembering information, and they may appear to be socially withdrawn, over-talkative, or have exaggerated emotional responses. ADHD is unique in the fact that it encompasses a child's hyperactivity along with inattentiveness. For example, a child may present with restless legs *and* the inability to pay attention for an extended period. It is important to

recognize that the disorder will be displayed differently among child populations depending on their age, gender, prenatal exposures, environment, schooling, etc.

ADHD is an extremely common comorbidity to accompanying neurodevelopmental problems. In fact, 30-50% of children diagnosed with ADHD also have at least one coexisting learning disability or conduct disorder (Neurodevelopmental disorders, 2015). There are strong correlations between ADHD and other learning impairments such as dyscalculia, dysgraphia, and other processing deficits. In fact, a 2018 experiment compiled a cohort of over 2,000 Spanish children and an even larger control group to examine the high prevalence comorbidity links between dyslexia and ADHD. The team noticed such an intense increase in ADHD cases being diagnosed alongside dyslexia, so they aimed to determine the accuracy of diagnostic criteria for the two together. Researchers were able to find that there are genetic links for the phenotypes influencing cognition overall (Sánchez-Morán, et al. 2018). This makes it easier for children to inherit ADHD along with another disability, like dyslexia, since cognitive abilities will be influenced by the same genomic groupings. Mirian Sánchez-Morán (2018) and his team also emphasized the importance of advocating for stricter and more rigorous diagnostic criteria for ADHD and its comorbidities to more accurately assess children.

ADHD used to just be considered Attention Deficit Disorder (ADD) until 1987 when the American Psychiatric Association created the additional disorder that could diagnose a child with primarily hyperactive symptoms (Neurodevelopmental disorders, 2015). Some professionals consider ADD to be another co-disorder for ADHD, given that a child with ADHD essentially *already has* ADD in itself, but there are few symptomatic differences other than increased activity. Additionally, ADD is rarely used as a diagnostic term anymore – instead children are often diagnosed with ADHD either being inattentive type, hyperactive type, or a combination of

both. In short, ADD is hardly referred to anymore, so its role as a comorbidity to ADHD can remain debatable.

**The Nature ADHD**

ADHD is a neurodevelopmental disorder originating from both genetic inheritance and environmental risk factors. Both nature and nurture play an equally contributing role in the presentation of ADHD in any given child. First, it is important to comprehend the heritable aspects of the disorder. There is statistical proof stating that polygenetic inheritance determined by patterns of illness within families is the main mode of ADHD transmission. About seven genes and gene groupings have been found to mediate increased susceptibility to ADHD symptoms, with the most influential being the DRD4-7 repeat allele (Faraone, 2020). The D4 allele plays a major role in novelty-seeking behaviors, such as short temper or impulsive decision making, which are main diagnostic components for ADHD. Given that the disorder is so heavily influenced by genetics, it is common for ADHD to run in families and be passed down from parent to child around 50% of the time.

Extensive research has also been done to determine the biological differences in physical brain structure and functioning for children with ADHD. Some dysfunctional developmental aspects of an ADHD brain include influential changes in gray matter, delay in cortical thinning, and impairments in white matter connectivity (Rodriguez-Martinez, 2020). Gray matter is mainly responsible for information processing and generating certain neural messages to sensory organs around the body, causing a child with gray matter anomalies to take longer to understand stimuli or have a lower IQ.  Cortical thinning, which typically occurs as an essential part of adolescence, helps children develop their visual memory, selective attention and other perceptual skills. Therefore, a child whose cortical area remains too thick for too long may be much later to adapt

social awareness skills for example. Lastly, white matter is an essential aspect of brain functioning that links different areas of the brain to the spinal cord, causing a child with white matter abnormalities to have more intensified hyperactive symptoms.

It is part of diagnostic criteria in ADHD for a child to struggle with remembering information, events, or concepts, specifically in the recognition phase of working memory. Recent studies have been designed to examine how these neurophysiological differences in children with ADHD affect their working memory. Elena Rodriguez-Martinez (2020) and her team at the University of Seville in Spain hypothesized that the impaired physical development of the brain would support the various memory impairments consistently seen in children with ADHD, along with limited executive functioning and deficits in response inhibition. This study compared the responses to a memory test by 29 ADHD children to 34 typically developed children, "…results have permitted to suggest that ADHD subjects present differences in stimulus processing in comparison to control subjects" (Rodriguez-Martinez, et al., 2020). These differences included a higher positive distraction rate in subjects with ADHD, inability to suppress distractors, and less focal attentiveness. This could be due to a reduced N2pc in almost all children with ADHD. N2pc refers to the visual cortex in relation to the field that the child is attending to, making it largely responsible for focusing ability and visual concentration (Rodriguez-Martinez 2020). N2pc deficits can explain why children with ADHD struggle memorizing information since it is visually encoded with less precision and accuracy as a result.

**Nurturing Symptoms in ADHD**

While nature plays a significant role in predisposing children to ADHD genetically, the prenatal environment also has significant, if not equal, impact. Maternal habits and environmental contaminants are among the most influential nurturing factors. For instance,

maternal smoking during pregnancy, alcohol use, or mental health stressors could all induce a preterm birth or low birth weight – both of which carry an increased likelihood for the diagnosis of a neurodevelopmental disorder, like ADHD. Environmental neurotoxins also hold extensive evidence for disrupting brain development in-utero and even after birth. Lead exposure studies have been conducted in Asia and the U.S. confirming that higher levels of lead in a child's blood directly correlated to higher chances of ADHD contraction (Neurodevelopmental disorders, 2015). The most common ways for children to be exposed to lead and other PCB's is through paint and unmonitored diets. Specific aspects of brain functioning, such cognitive flexibility, problem solving, working memory, planning, alertness, and response inhibition are all impacted as a result of abnormally high lead levels in the blood.

Family design and twin studies have been most effective in determining environmental roles in the presentation of ADHD. Resiliency was a major topic of interest for Maria Regalla (2019) and her research team as they conducted a quantitative experiment on siblings to explore environmental/socialization factors contributing to the presentation of ADHD. They measured resilience, the ability to emotionally cope with a stressor, on an adapted scale and they examined IQ scores in a group of children diagnosed with ADHD compared to their neuro-typical siblings. Regalla took into account the similar genetic makeup between groups of siblings and compared them to a potentially different socio-economic background and resulting anxiety levels. The team concluded that intelligence was not inherently impacted by socio-economic status, but there were significant findings for resiliency based upon the social environment. Children with ADHD appeared to emotionally recover more efficiently than their typical siblings as a result of their familial and social surroundings, "…unaffected siblings might have less family support, since their needs may be masked by their good behaviors and under-recognized by the family"

(Regalla, et al., 2019). Sibling pairs from a lower socio-economic background also dealt with more anxious symptoms within the home as a result of outside stressors brought in by parents. Children with ADHD in this case are receiving more attention for symptomatic behaviors, causing the unaffected siblings to cope differently and less effectively. This study confirmed that children diagnosed with ADHD will display more resilient tendencies when compared to a typically developed sibling (Regalla, et al., 2019). These findings suggest that the nurturing environment in which siblings of varying neurodevelopment are raised will often determine who can cognitively overcome adversity most adequately.

Given that children with ADHD seem to cope so well with stressors within their social environment, it may be easy to assume they interact with this environment at an average capacity as a result. That is not always the case for children with the disorder. Referring back to the concept of Theory of Mind, children with ADHD will exhibit difficulty with the overall social competence of other individuals. Theory of Mind is a cognitively complex concept, much different from emotion recognition, empathy, or general sociability (Lavigne, et al., 2020). Typically, children with ADHD are able to recognize when someone else appears angry, excited, frightened, etc and have shown trends in feeling sympathetic towards others. But, children with ADHD tend to struggle with other aspects of socialization such as sarcasm or false-belief tasks – performing similarly to children diagnosed with Autism Spectrum Disorder. This concept can be attested to the fact that Theory of Mind shares brain areas and neural communication with Executive Functions involving higher-level cognition (Lavigne, et al., 2020). For example, the frontal lobe is responsible for expressive language, which can explain why children with ADHD often take tone of voice too literally or seem quite “gullible”. Communication is chemically altered within the frontal lobe where social stimuli is processed, which is also where Theory of

Mind is understood. This can cause any social interaction, especially with older children who are more communicatively advanced, to be incredibly demanding for children with ADHD.

**Combined Efforts from Nature & Nurture**

Given that a large portion of ADHD cases are inherited, the role of genetics combined with environmental influence and life experience will greatly impact how the disorder is displayed by children. The biological makeup of a child with ADHD will interact most noticeably with their social environment, again, similar to that of children with Autism. The lifestyle of a child with ADHD will almost always impact the severity of their symptoms. For example. The amount of sleep they are getting, how much screen time they are allowed, and schoolwork load will all contribute to their symptoms of inattention and hyperactivity to some extent. A comprehensive study performed by Joel Nigg (2020) and his team at Oregon Health & Science University evaluated emotional regulation in response to environmental stressors in inherited cases of ADHD in children. They gathered a group of over 500 children, ages 7-12, formally diagnosed with ADHD and a typically developed control group to determine temperament through questionaries and structured interviews. Comparing the two key groups, researchers measured rates of anger-irritability and sensation seeking behaviors when the child may instigate reactions from others. They concluded that children with ADHD naturally have a genetic predisposition to lower impulse control when exposed to environmental stressors (Nigg, et al., 2020). This information has already been regulated through the DSM and other diagnostic manuals, but Nigg's study confirms that certain aspects of temperament, like anger-management and surgency-sensation seeking, are more commonly dysregulated in children with ADHD.

## Conclusion

The importance of combined contributions from both nature and nurture will display neurodevelopmental disorders, like Autism, Hemimegaloencephaly, Down Syndrome, and ADHD, in varying degrees. In some cases, genetics and the hereditary biology of certain disorders will be most influential – this concept is seen more commonly in HME and DS. While other disorders, like ASD and ADHD, are more heavily influenced by environmental factors and socialization in combination with their genetic makeup. Regardless, children have the potential to acquire neurodevelopmental disorders congenitally, but lifestyle choices and uncontrollable stressors within the environment will often determine the severity of their symptoms.

### Biopsychosocial Model of Wellness

The Biopsychosocial Model of Wellness is a well-known and largely accepted interdisciplinary model that coincides with the theory of Nature vs Nurture. The model encompasses the main factors of overall health and how they interact to determine the outcome of wellness for an individual. These determining factors are biological, psychological, and social influences. Emphasis is placed on the crucial and constant exchanges throughout the entire diagram that regulate an individual's human experience. Similar to that of nature and nurture, "The biopsychosocial model argues that any one factor is not sufficient; it is the interplay between people's genetic makeup (biology), mental health, and behavior (psychology), and social and cultural context that determine the course of their health-related outcomes" (Biopsychosocial model).

Biological influences on health in accordance to the Biopsychosocial Model of Wellness include a child's genetic makeup and any history of physical trauma – like brain damage or prenatal exposures. This model also indicates that any genetic predispositions in the biological

makeup of a child will have the most significant impact on the other aspects of the model itself. Social influences on health include environmental factors such as socioeconomic standing, culture, technology access, religion, family circumstances, peer relations, and more. Social factors also include a child's physical environment and surroundings – encompassing a majority of "nurture" concepts. Psychological influences on health are often the result of the previous two factors forming a foundation for a given developmental disorder. These factors include coping abilities, self-image, emotional response, and temperament – to name a few. Individuals with genetic or environmental vulnerability are more likely to display self-destructive or socially unacceptable behaviors as a result.

Concepts and ideas from the Biopsychosocial Model of Wellness are incorporated throughout the theory of Nature vs Nurture when it comes to psychological illness. Both approaches involve a complete review of all potential factors contributing to mental health, which in this case simultaneously contributes to the presentation of various neurodevelopmental disorders. A comprehensive understanding of the origination of various disorders using both concepts will not only assist children in getting a more accurate diagnoses, but also a more effective treatment plan.

**Treating Neurodevelopmental Disorders**

Treatment plans for children diagnosed with any neurodevelopmental disorder require extensive involvement from teams of medical professionals in order to provide the highest quality of life for the child. Of course, this begins with a methodical evaluation and understanding of how the disorder originated and how the method of origination effects the presentation of symptoms in the individual. It is also critical to understand that most

neurodevelopmental disorders cannot be cured. Instead, treatment plans typically incorporate techniques for symptom management like therapy and prescriptions.

Children with Autism Spectrum Disorder have found success through a variety of treatment options, since disorder severity will range across the spectrum. Early-intervention treatment, like ABA therapy or mood-stabilizing medication, tend to be most successful for mild cases where sensory seeking behaviors and social skills are prioritized. Intense behavioral interventions have been proven to reduce problems behaviors, such as aggression and stereotypy, in children with more severe cases of ASD. Quantitative studies show that the most effective form of symptom regulation for profound cases of Autism in children was positive combination interventions (Heyvaert, 2014). This plan emphasizes neutral redirection, non-contingent reinforcement, and performing tasks that revolve around the child's strengths in order to earn meaningful rewards. Positive combination interventions tend to be more engaging and motivating for Autistic children when compared to a consequence-based treatment plan.

Children with Attention Deficit Hyperactivity Disorder see similar success rates when it comes to a treatment plan involving both therapeutic services and medication. There are multiple prescription preferences among children with ADHD depending on if they aim to control impulsiveness, hyperactivity, inattentiveness, or a combination. Family-based therapies are also recommended for these children to include and educate all family members on symptomatic concerns as well as individual progress.

Hemimegaloencephaly and Down Syndrome are more unique in terms of their treatment strategies. Both disorders are solely congenital and incurable, with symptom management strategies being limited. Children with Down Syndrome are almost always enrolled in special education programs in school, as are most other neurodiverse individuals. A majority of

therapeutic services for DS children are only available/provided during the school day, which leaves a major portion of their life without opportunities for personal improvement. Other than this, support groups and organizations, like the Special Olympics, have been put into place for children with DS overtime to implement social inclusion. Children with HME on the other hand tend to receive less inclination for cognitive or behavior-based therapies to work on social communication. Instead, prescription medication to control seizure activity is often the main, and only, priority for doctors.

Regardless of the treatment method, children experiencing a significant impairment on their daily living as a result of a neurodevelopmental disorder are typically monitored for their entire life. Meaning that treatment plans and goals often evolve throughout development. Disorders arising from genetic abnormalities are often diagnosed earlier in life, allowing for more immediate treatment and accurate outcomes. Environmental and social circumstances will also play a major role in determining which treatment avenue may work best for the child to achieve their personal goals and highest quality of life.

**The Beauty of Neurodiversity**

The trend of increased education around neurodiversity over the last couple of decades has been a major progressive step in the world of psychology. Maintaining this urgency in spreading awareness is also important in order to create a world that understands the reason for behaviors that neurodiverse children display in social settings. Establishing a more accepting society begins with knowledge and appreciation for neurologically diverse individuals. Even though children with neurodevelopmental disorders are bound to face extraordinary challenges, there are endless lessons to learn by viewing life from their unique perspective.

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