

## CHAPTER 2

### UNDERSTANDING HOW LEARNING WORKS

If we want to find a way to help kids struggling in school, a good place to start is to understand how learning happens in the first place. We're going to show you how a child is put together, and where problems can occur along the way. We'll let you know why we are defined by the way our brains are put together. Once we understand how a child changes over time, it will be much easier to help them at any age.

It would be easy to list common learning problems kids have, and the numerous ways experts go about "fixing" or trying to mitigate problems. The strategies they suggest to help kids with learning disabilities are all valid, and we will recommend the best ones at length. But just like taking out weeds in the garden, if you don't get to the root of the problem, it will just grow back. Trying to plaster over mistakes does not help the overall structure of a crumbling wall- it just masks the underlying issue. In order to help a child struggling in school, you really need to understand if their problems are structural or cosmetic. The difference between these two sorts of problems will determine what kind of strategy will work best.

So let's talk about how learning works. Learning is both amazingly simple and complex. While it happens all the time when we aren't really paying attention, it requires a lot of action on the part of our brains. For example, the brain has very fast pathways, like superhighways, and smaller pathways, more like driving through a small town or neighborhood. Our brains are constantly sending signals down many of these roads, at varying rates of speed. When we are learning something new, however, our brain functions like a NASCAR driver, taking turns at full speed, under control, yet eager to win the race. When we "get it", it is like making it to the Winner's Circle- there is a sense of satisfaction and accomplishment that can't be matched.

Our brains are constructed to learn, and more precisely, so that we will do more of what feels good to us, and less of what feels bad. Dr. Mel Levine<sup>1</sup> has said "Success is a Vitamin". Success and accomplishment make us feel good about ourselves, and our brains are designed to release hormones and neurotransmitters that reinforce this good feeling over and over. Too often, kids don't get this feeling from school.

For many kids, school does not make them feel competent and successful. School is a place where they are "sent" to spend their day, rather than a place they get to go. It's a job, not a trip to Disney World. It's not something they look forward to, it's more like a job you do just because you need the money, or in their case, because they need the knowledge. For kids who are struggling in school, it's like walking all day in a pair of

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<sup>1</sup> Dr. Mel Levine is one of the foremost neurodevelopmental pediatricians in the country. He is an acknowledged expert on learning disabilities, has published a number of books, and has started the All Kinds of Minds Institute, which is trying to help schools teach with the individual differences of children in mind.

bad shoes. School may keep you protected from the sharp edges of life, but it also rubs and cause blisters. Kids just can't wait until the end of the day, when they can finally take off those shoes and relax. It's no wonder so many kids struggle with homework- the daily grind of school is prolonged by more of the same at home, when all they want to do is blow off steam and be able to do something that makes them feel good for a change.

The reason why everyone harps on and on about the importance of self-esteem and protecting the self-esteem of kids is this: If you feel good about yourself and your accomplishments, you are much less likely to look for more self-destructive ways to make yourself feel better. For example, if you take a closer look at most of the addictive and self-destructive behaviors people adopt, most of these hijack the brain's reward system and mimic the sense of excitement we get when we learn something new, or they depress and cover the anxiety and pain we feel with failure. It's long been acknowledged that simple measures like parental involvement reduce the chance kids will get involved with drugs and alcohol. This is because when kids feel connected to their families and that they are important, competent, valued people, there's no need to seek acceptance elsewhere.

## **The Brain and Children**

We're taking a tour through the development of a kid's brain for a bigger purpose. As parents, we need to understand what behavior is part of the fundamental architecture of who kids are, and which parts are still under construction as they grow.

Humans are born early, before their brains are fully developed- if we waited to be born until after our brains were finished, we'd never fit through the birth canal! As a result, a significant part of our brain development happens outside the womb. As the brain grows, it becomes affected by our surroundings and the experiences we have. Throughout childhood, our brains slowly become more sophisticated, and we can begin to think in more complex ways. Bursts of brain development happen at certain ages and within certain period of time, often referred to as windows. Before these windows open, kids aren't capable of some things, because they just don't have the brain hardware yet to run these more complex programs and behaviors.

This section is all about understanding how this process of brain development and learning happens, and where detours can occur along the developmental road. Small detours are fine and normal, but like driving in a new town, it is best to get back on the main road as soon as possible before you get lost. The bigger the detour off the developmental road, the more likely the problem will get larger and harder to manage over time.

## **The Science of Learning**

We learn new things every day, and the process happens as naturally as breathing. If this is the case, why do some people struggle with learning so much more than others?

Why can some people memorize phone numbers in two seconds, and others can't even remember their own zip code?

When you look at the process of learning close up, you can start to appreciate the complex orchestration of events that come together, and why sometimes things go wrong. On one level, learning requires input from the senses (like seeing books on a shelf), coordinating this information with what particular thing you're looking for (a recipe for your favorite dessert), and then making a choice (picking the book that has that delicious cake recipe in it). You then have to turn this choice into action, such as picking up the book and finding that recipe, even if you are subsequently disappointed because you forgot to buy the eggs!

On one level, learning requires many parts of the brain to act and respond in a coordinated way to allow the whole person to act. On a more microscopic level, learning is also a series of chemical reactions and messages sent between nerve cells. The messages allow individual cells to act and react, both individually and as a group, to make the whole picture come together, like a jigsaw puzzle. So learning occurs on a biochemical level, as nerve cells talk to each other, and on a larger stage, where the brain and body work together.

When learning breaks down for kids struggling in school, we can sometimes begin to solve the problem by looking at whether it is a biochemical problem or a larger coordinating of signals, or traffic problem. A great example of this is kids with attention deficit disorder/ attention deficit hyperactivity disorder- commonly known as ADD or ADHD.<sup>2</sup>

People with ADD/ADHD can seem really busy and often disorganized, making it easy to assume that their brains are sending signals all over the place too, all the time. But if you look at brain scans of people with ADHD, surprisingly, their brains are actually under-active, rather than overactive. The reason why ADHD people seem so busy all the time is that their brains are constantly looking for stimulation from the environment, to keep them awake and functioning optimally.

This helps explain why stimulant medications work so well in treating ADHD. Stimulants speed up the brain's base level of activity. Instead of taking someone who is moving a million miles an hour and souping them up more, it actually speeds up their brain so they can coordinate their movements and actions better. By fixing the under-stimulation problem on a biochemical level, you change the outward behavior to one that looks like slowing down. The best example of this in every day life is the common addiction to coffee and caffeine. Like any other stimulant, caffeine is a known performance enhancer and works to "get us going" in the morning. The extra boost many of us seek from double lattes is the same one people with ADHD get from medication – they just get it at a precise dosage, where most people self-medicate at Starbucks.<sup>3</sup>

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<sup>2</sup> ADHD has become the shorthand for this learning disability, so we will use that as the general term.

<sup>3</sup> See also Hack # 92- Make The Caffeine Habit Taste Good; *Mind Hacks: Tips and Tools for Using Your Brain*; Tom Stafford & Matt Webb, O'Reilly Media, 2005. Hack #92 mentions that caffeine reaches into

Understanding learning on the microscopic level and on the “whole person” level is important, because interventions for kids with learning problems often involves both levels. For example, as we mentioned above, kids with ADHD respond well to stimulant medication, but kids with other learning problems do not. Experts are finding that kids with dyslexia, for example, have a less efficient connection between different sections of the brain, making reading more labor and energy intensive. Likewise, kids with fine motor problems can find writing a real challenge, because they have problems coordinating the signals from their brain with the movement of their hands and fingers. Each of these students face a different set of challenges in school, but one is happening more on a biochemical level, where the others involve problems in coordinating signals and actions, on a slightly higher level of functioning. In order to find a good solution to a struggle at school, you need to understand on what level the problem occurs.

## **The Brain And You**

The brain, unlike a computer, evolves over time, in response to our experiences. This change over time is complex enough that we have even divided up its care among different professionals. Medical doctors deal almost exclusively with the hard-wiring problems of the brain. They are the brain mechanics, so to speak. Psychologists and their medical counterparts, psychiatrists, are devoted to the software portions of the brain, or how thinking and behavior work. Educators, meanwhile, can be seen as the upgrade specialists. Education tries to instill new concepts and skills, ranging from the mechanics of holding a pencil, to reading, to communicating to each other through writing, to understanding and manipulating numbers.

The compartmentalization and division of brain functions among professionals makes diagnosing and betting treatment for kids struggling in school difficult. How do you know which specialist to see? Where do you begin to look for answers? What is normal, anyway? In order to figure out where to go for answers often requires an understanding of the problem you probably don't have. Is the problem chemical, behavioral, or simply due to inadequate teachers or schools? Is it really due to problems at home? Parents are vital to coordinating information between each of these professionals, and for keeping a perspective on the child as a person.

## **One Stop Shopping for Answers?**

The fields of medicine, education and psychology haven't historically worked well, or closely, together. Medical doctors have their own biases, and look at school problems like any other disease process. They ask whether or not the problem is causing a significant problem, and only then, are many willing to act. This can mean waiting until a kid starts to perform poorly on a consistent basis in school before considering testing or medication. Teachers are taught very little about learning problems in school, or how to spot one based on a child's classroom performance. Add to this picture that

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every bodily fluid within 20 minutes of being ingested, and experiments have shown that it is a known mental performance enhancer, allowing you to solve chess problems better than without it.

most psychologists that test for learning problems see patients on referral from other professionals, and you begin to understand that educators and doctors act as gatekeepers, but their experience and practice bias can prevent them from making the referrals kids need.

Further complicating the problem is that very few professionals have knowledge about medicine, psychology and education and how they overlap. The first graduate school program to try to unify the overlaps between medicine, education and psychology only opened in 1998, at Harvard University.<sup>4</sup> Until then, these different fields of research have been divided and isolated, despite the fact that all three areas intersect when you look at kids and school.

For example, neurologists have known for years the basic functions of the brain (e.g. memory, language, vision, etc) and where these functions are located. However, this information has had little real world impact for students. Medicine has done extensive research into the way different medications improve our functioning and learning, but doctors still do not fully understand how one educational program will be better for a child than another. Psychologists are great at studying behavior and testing intellectual skills, but often can't translate their data into a plan of action for the classroom.

Educators, on the other hand, study students from a still another perspective. They look at learning in children, but have not always considered the brain's structure and functions as reasons behind why some things work and some things do not. As G. Reid Lyon, former Chief of the Child Development and Behavior branch of the National Institutes of Health, has stated: "The toughest challenge we have is in moving the science to the development of teachers and their preparation, such that what they learn is actually objective and is based on converging evidence rather than philosophies, belief systems, or appeals to authorities."<sup>5</sup>

To further complicate things, the media eagerly latches on to any new scientific discovery, learning program or tool and gives us a "quick and easy way" to use this information for our children's benefit, even when the information was never meant to be applied in this manner. A great example of this was the famed "Mozart Effect". Based on several small studies, researchers found listening to classical music could help some university students perform better on cognitive tasks, like doing puzzles, in a psychology laboratory. This was taken by the media to mean playing classical music for children from birth, or even in utero, would make kids smarter. This over-interpretation of the

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<sup>4</sup> Harvard University began the first graduate school of education program to unite these fields of study in the late 1990's. In a master's program entitled "The Mind, Brain and Education", students study cognitive sciences, neuroscience and educational practice, with the goal being to enhance interdisciplinary collaboration. Its purpose, in part, is to move educational research from being based on theory and observation to research-based practices, as in medicine. By understanding how these complex fields inter-relate, students will be able to develop a host of proven "best practices" in education to teach kids in a way that best fits with their brain development over time.

<sup>5</sup> Interview with G. Reid Lyon, by David Boulton, published on the webpage for Children of the Code; <http://www.childrenofthecode.org/interviews/lyon.htm>

data led a state governor to partner with Sony music to make sure every newborn in his state received a classical music CD.<sup>6</sup> While no one will deny that being exposed to classical music is lovely, there has been no reliable evidence to date that listening to classical music will significantly improve a child's IQ score, or even impact any child's ability to learn.

As parents, we need to look at media reports and scientific research about learning with a critical eye. In order to make reasoned decisions about interventions we should try, we need to consider what is real, and what is myth or wishful thinking. The only way to sort the tremendous amount of information available, in order to best help our kids, is to have a basic understanding about the brain. We cannot hope to give you all the information you would learn in a graduate degree program in this chapter, but we hope to give you an overview of how the brain and learning work together, so you can be a better advocate and learning partner for your child.

## **The Brain For Beginners**

The brain is complex, and understanding how it works can be challenging. It is more than just a huge computer for the body, although this analogy is helpful. Unlike a computer though, whose components are fixed after it is manufactured, the brain develops over the course of our lifetimes, and is constantly changing, regardless of our age.

It used to be thought that we were all born with all the neurons (brain cells) we would ever have. With the help of new imaging tools, scientists have found that the brain actually continues to change over the course of our lifetimes. While most of the growth in the bulk number of neurons happens early on as children, the key to the magic of the brain is the way these cells communicate with one another. We now know that certain areas of the brain become more active and mature over time. The bulk of development continues, in spurts, until we are around age 22. After this point, neurons will still forge new connections with one another, but the main highways are completed. Most construction of new signals takes place on a more local level for adults, while unused roads and pathways continue to wither away. This view of the brain as an ever-changing part of ourselves is having a tremendous impact on how we understand how the way kids think and learn in school.

## **From the Beginning**

The brain starts to develop as part of the central nervous system at the earliest stages of development. As an embryo, the very first structure that begins to form is the neural crest, a line of cells from which the brain and spinal cord will emerge. From this neural crest and elementary nervous system, the rest of the body plan of the embryo develops.

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<sup>6</sup> Governor Zell Miller of Georgia, now Senator Miller. <http://miller.senate.gov/bfb.htm>

The brain and nervous system begin to develop an information highway to communicate to the rest of the body as the embryo and body plan form. This includes the ability to take information from the periphery and process it, so that it makes sense to us as we begin to order our view of the world. It's this interaction between the outer world and the inner world of our brains that is endlessly fascinating. The brain takes and processes concurrent information from our eyes, ears, taste buds, nose, and limbs, while also orchestrating the movement of our muscles, regulating our breathing and blood pressure, and other responses to our environment, all at the same time. It is a multi-mode processing system any computer scientist or engineer would envy.

### **The Nervous System- The Hard Wiring**

Once the main pathways of the brain and nervous system are laid down, the fine tuning begins. Let's take a moment to explain how the nervous system communicates information, because it will become important a little later on, when we look at why some kids struggle with learning, and which parts may be due to the early development of their brains.

Our central nervous system [CNS] relies heavily on the information from the peripheral nervous system [PNS] about our environment and how we react to it. The PNS is in charge of receiving messages and information from the environment and sending it to the brain. The PNS then receives instructions from the brain on how to react to the information, and acts on them, such as causing our muscles to move our hand away from danger. All of the information about temperature, place in space, terrain, and the like is communicated almost instantaneously between the PNS, brain, and CNS, without the need for conscious thought.

The PNS is easier to when you divide it into two subdivisions- the "autonomic" and "sensory – somatic" parts. The sensory-somatic division is in charge of delivering information from the senses to the CNS, such as whether your hand is touching something hot, or you smell smoke. It then receives the instructions from the brain to "investigate whether the toast is burning", for example, and makes the necessary muscles contract to allow you to get up and go see if the kids tried to toast a whole peanut butter sandwich again.

The autonomic system, in contrast, controls automatic functions that keep us alive, such as regulating our heartbeat, breathing, digestion, and functions of glands. For example, if we are faced with something scary, like an amusement park ride or our kid's principal, the autonomic system receives a message from the brain to increase adrenaline, which will also increase heartbeat, breathing, and sweat production, as we prepare ourselves for this situation we perceive as difficult or dangerous.

People who participate in high risk activities, like skydiving, driving race cars, or even supervising kids with ADHD, can learn to control their autonomic responses. People can counter the "natural" instructions they get from their brain, which explains the ability of kids to enjoy monster roller coasters despite the natural instinct of most mothers to run and run and hide. In fact, the "rush" many people get from riding roller coasters, for

example, is a result of the autonomic nervous system going into panic mode, sending a message to the brain that says “We are going to fall and die or **at least** get seriously injured!” while the brain tells the autonomic system to “Relax and enjoy the ride!” It is constantly changing throughout our lives, regardless of our age. Where it used to be thought children had all the neurons (brain cells) they would ever have at birth, new information is proving this theory wrong. With the development of sophisticated imaging tools, researchers are discovering that the brain is far more dynamic and changing throughout our lives than was previously believed. For example, new research into brain development is showing us that the brain keeps changing and does not fully reach its “maturity endpoint” in development until at least age 22. Long after this point, the brain will still be forming new connections, be able to learn (and forget) and change in dynamic ways throughout our lifetime. This new view of the brain as an ever-changing part of ourselves is having a tremendous impact on how we understand the intellectual development of children over time, as well as what happens as the brain ages.

In comparing the brain to a computer, it sometimes is easier to think of it as having “hardware” and “software” components. The “hardware” in people is the brain, its basic wiring, and the input devices we can modify but not change, like our eyes, ears, sense of touch, etc. The software is our whole cognitive framework, that encompasses our ability to learn and interact with our environment. Often there will be little we can do to change our hardware, or basic wiring, but we can modify or upgrade our software, so to speak. As we grow from infants to adults, we are gradually able to think in more sophisticated ways, and change our behavior based on our experiences. Certain skills can “come online” at certain ages, such as most children develop the ability to read around the age of 6, or the development of critical thinking in the late teen years. For children with learning disabilities, it becomes very important to keep in mind that if their problem is based on faulty wiring, it probably will always be part of their make-up and cannot be permanently “fixed”. In other words, you cannot “cure” a learning disability. However, because people are always able to learn, you can “upgrade the software” and make the learning process more effective and efficient by teaching that person to work with their given wiring, rather than against it.

In the following section, we will explain how the brain and nervous system form and function, so that you can better understand how the “wiring” of a person works. Following the “hardware” section, we will describe how cognitive functioning develops, or how the “software” changes over time, and when to expect certain skills to develop in kids as they age.

## **From the Beginning**

The brain starts to develop as part of the central nervous system at the earliest stages of development. As an embryo, the very first structure that begins to form, differentiating an embryo from a loose group of cells, is the neural crest, a line of cells from which the brain and spinal cord will emerge. From this “neural crest”, the rest of the body plan of the embryo develops. This miraculous symphony of cell migration, cells



grouping together and deciding to form organs, muscles, bones, blood cells, and everything that will be part of a whole person at birth, is ridiculously complex. (It is equally amazing that it all goes off without a single mistake so frequently.) The brain and nervous system develop an information highway to communicate to the rest of the body from even the earliest stages of development, as well as the ability to take in information from the periphery and to process it in such a way that it makes sense to us as we begin to order our individual view of the world. It is this interaction between the outer world and the inner world of our brains that is endlessly fascinating. The brain can take and process concurrent information from our eyes, ears, taste buds, nose, and limbs, while also orchestrating the movement of our muscles, regulate our breathing and blood pressure, and otherwise respond to our environment, all at the same time. It is a multi-mode processing system any computer scientist or engineer would envy.

At birth, the brain is not “finished”. It will continue to grow, change and mature over our lifetimes. In response to our experiences of the world, the brain cells, or neurons, will form connections with other neurons, forming a complex web of circuitry. As some circuits are formed, other circuits which are less used tend to be “pruned”, forming more efficient highways of information through the brain over time. This process of hardwiring our brains takes years, and in fact, we have now learned that even as adults, our neurons are constantly forming new synapses as we learn new information and have new experiences. While the most active period for synaptic formation takes place before 1<sup>st</sup> grade, the bulk of our learning takes place after the number of synaptic formations stabilizes, at about age 7.

### **The Nervous System- The Hard Wiring**

In order to begin to understand how the brain develops and changes over time, a quick overview of the whole nervous system is in order.

Our central nervous system (the Brain and spinal cord, CNS for short) relies heavily on the information from the peripheral nervous system about our environment and how we react to it. The peripheral nervous system is in charge of receiving stimuli from the environment and sending it to the brain, and likewise receiving the information about how to react back from the brain, so that the peripheral system will cause muscle fibres to contract, and cause us to move our bodies accordingly. All of the information about temperature, place in space, terrain, and the like is communicated almost instantaneously between the peripheral nervous system, brain, and central nervous system, without the need for conscious thought as we move through our environment.

Understanding the peripheral nerve pathways is easier when taking them in two smaller subdivisions- its “autonomic” and “sensory – somatic” parts. The sensory-somatic division is in charge of delivering information from the senses to the CNS, such as whether your hand is touching something hot, or you smell smoke. It then receives the instructions from the brain to “move your hand before it is burned” or “investigate whether the toast is burning”, for example, and makes the necessary muscles contract to allow you to move your arm or go see if the kids tried to toast a whole peanut butter

sandwich again. The sensory system also handles all the cranial nerves, which include those responsible for regulating oral motor movements, facial muscles, movement of the eyes, swallowing, and chewing, among other functions.

The autonomic system largely controls those automatic functions that keep us alive, such as regulating our heartbeat, breathing, all aspects of digestion, as well as functions of the glands. It communicates information to the CNS, and reacts to instructions sent from the brain. If we are faced with something that scares us, the autonomic system may receive the message to increase adrenalin from the adrenal glands, which will also increase heartbeat and breathing, as we prepare to run or otherwise react to the perceived danger. Many people who engage in high risk activities like skydiving, NASCAR races, or soldiers, learn to control many of their autonomic responses. Through long term training and learning, people can learn to counter the “natural” responses they get from their brain, in order to act appropriately to keep themselves safe in dangerous situations, and essentially learn to ignore the natural panic and fear response information they receive from their nervous systems. In fact, the “rush” many people get from riding roller coasters, for example, is a result of the autonomic nervous system going into panic mode, sending a message to the brain that says “We are going to fall and die or **at least** get seriously injured!” while the brain tells the autonomic system to “Relax and enjoy the ride!”

For children, every new experience from the moment they are born provides sensory stimulus to the brain that drives its development and functioning. Smell, taste and touch are some of the most important “instinctual” sensory input we get as infants. These three senses help us begin to make emotional attachments to our parents, find nutrition, and begin to frame our world. Particularly since our vision is not clear at birth, and we haven’t had enough auditory input to really begin to differentiate sounds as language, music, or just background noise, for example, we are almost completely reliant on our smell, taste and touch to begin to make sense of our world. These early, highly sensory experiences have been shown to be critical in whether or not we thrive as infants, and in turn, how we will turn out as older children and adults.

As our vision improves in infancy, we learn to focus and track object, and gradually our hearing begins to allow us to discriminate between the sounds of speech and background noise. Vision and hearing tend to take over and become more important in our perceptions of the world, as higher cortical functions of speech, language, and learning all begin to interact, rather than solely relying on our smell, taste, and touch as our primary means of experiencing the outside world.

## **Brain Development and Stimulation**

### **Nature vs. Nurture**

As scientists continue to try to understand how children acquire skills, and why some individuals do not, they are examining what early stimulation (or the lack thereof) does to the physical wiring of the brain and its cognitive function. If there is too much stimulation too early, will this “shock” the nervous system and lead to learning problems

down the line? If there is not enough appropriate stimulation during childhood, can the child still be successful? Answers to these questions are still being sought, although progress towards understanding how the young brain grows is increasing daily. It is clear however, that input drives development in both positive and negative ways.

We know that the loving touch and nurturing of an infant leads to faster growth and happier infants. From early research on primates in the 1950's, a researcher named Harlow discovered that touch and physical comfort was as important as nutrition to the psychological development of primate infants. While this is a given today, these early psychology experiments were the first steps to try to find out how nurture, or the experiences a child has in their early life, affects, or even supercedes nature, the genetic gifts and predispositions we receive from our parents.

We are learning that while some infants may fail to thrive if they get too little stimulation after birth, too much stimulation, too soon, can be equally debilitating. For example, doctors take measurements of children at checkups to check for normal growth and development, but also for Failure to Thrive. This condition seems to be caused by stress in infants and ineffective nurturing, which can cause children not to eat and grow as expected, putting them at risk for developmental problems. Scientists are continuing to study how nurture affects all aspects of brain development, but it is clear that babies need touch and love as much as they need food and nutrition to develop well. In contrast to Failure to Thrive, which may be caused in part by too little environmental stimulation, we also know that too much stimulation can be debilitating for children.

Infants born prematurely are known to be at greater risk for a wide range of developmental problems and learning disabilities than full term infants. Researchers have found that by redesigning the Neonatal Intensive Care Units ("NICU") in hospitals, they can reduce the number of developmental problems experienced later on. Since the brain is not yet fully developed at birth in full-term babies, for premature infants, the brain is even less ready to meet the outside world. Instead of the older, noisy, bright, and jarring intensive care units that were similar to those for adults, premature infants are now being cared for in specially designed, low-sensory input environments. In the new NICUs, babies are protected from the huge amount of stimulus including light, sound, touch, and other stimuli they would normally begin to receive immediately after birth.<sup>7</sup> Low light conditions, quiet, soothing, gentle touch, and the like are used to reduce the stimulation the baby would otherwise encounter, in hopes that this will mimic the protected environment of the womb as closely as possible. By protecting premature infants from becoming overstimulated, Doctors are hoping to normalize brain development in premature infants and head off later developmental problems.

Stimulus clearly drives development, and we are learning that having too many brain cells may be just as debilitating as having too few. Despite the common misconception that the more neurons you have, the smarter you are, there is not a direct correlation between neuron number and intelligence. While children with Down's Syndrome, do have lower synaptic density, or lower connections between neurons that

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<sup>7</sup> The Secret Life of The Brain, Episode One "The Baby's Brain: Wider Than the Sky". PBS Video, 2000.

regular children, we are finding that having too many connections between neurons can be just as devastating. New studies are showing that in conditions like autism, the brain may grow too big, too quickly. While it is unclear why this brain overgrowth occurs, it is clear that children with autism spectrum disorders can have long term problems in functioning. It seems having the optimal number of synapses, and having an effective

## **Exploring the Environment and Perception**

Unlike a computer, the brain's wiring continues to grow and change constantly in response to the environment. New connections are formed, and other less used pathways seem to wither and get "pruned" off the circuitry pathways. For children to develop well, they need input that is nurturing in the classic sense- it provides enrichment, protection, a feeling a safety and well being, and allows the child to learn effectively. The sense of touch is clearly important in a child's early exploration of the world, as they seek to touch everything, put things in their mouths, and otherwise explore their worlds. With each of these actions, the infant's brain is forming new connections and memories that will be with us for a lifetime.

## **The Senses**

Our brain receives information about the outside world through our five basic senses – Sight, hearing, touch, smell, and taste. This information is delivered as nerve signals from the sensory organs which our brain then interprets using our "cognitive processes" in order to make sense of the information delivered. Very much like a keyboard and mouse for a computer, the senses take the "input" from their source and then "process" or interpret this information in a useful way. If the data received from these sources is not accurate, or is not received at all, the processing of the information received will likewise be faulty and inaccurate. Likewise, if too much information is received, it can overwhelm the ability of the brain to process the information, and cause the system to shut down.

The senses are also where the division between medicine and psychology begins. Most medical fields are oriented towards treating a disease or defect, so Ophthalmologists, for example, treat malfunctions of eyes, while Otolaryngologists (Ear Nose and Throat or ENT doctors) treat malfunctions in the ears, nose and throat systems. Like mechanics or computer technicians, their primary job is to fix the input or sensory devices only. Any subsequent problems of cognition, such as lack of depth perception in vision, or deficits in being able to express oneself through language, fall to different therapists, psychologists, and psychiatrists to sort out. Unfortunately, this is also why impairment of a primary "input" such as hearing, which clearly may delay a child's speech, gets classified as "developmental delay". A problem which has begun as a medical dysfunction, can turn into one that is classified as primarily psychological in nature.<sup>8</sup>

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<sup>8</sup> As a side note, in the land of insurance coverage and treatment options, this is an example of a medical problem that would receive coverage under health insurance plans

## Vision

Certain areas of our brain become specialized over time to interpreting specific kinds of information. For example, the visual cortex becomes very specialized in analyzing the information received from the eyes, identifying it, and allowing us to act on this data. Newborns see very indistinctly at first, and do not have binocular, three-dimension vision. After a few months, after significant “sorting” of neurons and feedback to ocular muscles regarding focusing and movement of the eyes, babies are able to follow objects, identify members of their family on sight, and really begin to use their vision as a tool to learn about their world. As you can imagine, if the information being transmitted to the brain from the eyes is not good due to a fault in the eye itself or its ability to focus, the brain will only process the fuzzy information it is being fed from its outside monitor of the world around.

If something deprives a child of early vision or early visual stimulus, they may never be able to see. In 2000, Michael May, a man blind from an accident at age three, had an operation to correct a defect in his eyes that prevented him from seeing.<sup>9</sup> Although his brain received nerve signals from his eyes, his visual cortex hadn’t received any information for over forty years. Since his brain learned about things mostly by touch, scientists were fascinated to see how this repair to his vision would affect him. Mr. May is one of the incredibly rare people who have had this kind of experience, and in essence, he has been forced to “relearn” how to see as an adult. He can see colors, and motion, but recognizing faces, including that of his wife, requires additional cues from the environment, like hair color and length. Mr. May has said he has gotten better at guessing these things over the past few years, but he still feels as if he is guessing about many of the things he sees. He describes his vision as being like walking into an abstract painting, with many colors and movement, but the clarity and distinctness of images is largely absent.

Similarly, people who have been blind from birth may never be fully able to interpret the “visual noise” they will see if their vision is restored. For example, a project being run through the Massachusetts Institute of Technology is helping to restore the sight of many children with cataracts in India. The MIT group has found the restoration of vision is most successful when done early.<sup>10</sup> The later in life the corrective surgery is done, the more severe the reaction can be for the patient who can now see a world that

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that then becomes a brain or psychological problem after the age of three. This means that treatment is no longer covered by most insurance plans, but is instead deferred to schools for treatment as a “developmental disorder”, an educational or psychological classification.

<sup>9</sup> NPR, Morning Edition, August 23, 2004, interview with Michael May; NPR Talk of the Nation Science Friday, August 26, 2003, Interview with Ione Fine, Assistant Professor, Ophthalmology, Doheny Eye Institute, Keck School of Medicine, University of Southern California, Los Angeles, California.

<sup>10</sup> “Sight Unseen”, Massachusetts Institute of Technology News Office, August 25, 2003  
<http://web.mit.edu/newsoffice/2003/sinha.html>.

was formerly dark and isolating. Many of the older patients have developed depression, or simply decided it was easier for them to function day to day by continuing to act blind and not use their eyes. This is probably due to the fact that the brain has never had the opportunity to learn how to cognitively interpret the images that have been restored to them. Even though the “input” from their visual system is functioning perfectly, the amount of information is simply overwhelming and simply overloads their circuits.

Vision is not isolated from our other senses. Vision allows us not only to locate objects in space, but helps us to sense things like speed, motion, perspective, distance and the like. For example, balance and coordination can be affected by vision. If you try to balance on one foot, it is much easier to do if you have your eyes open and focus on a point in space. If you close your eyes, you no longer have the feedback from your vision about where you are in space, and can quickly feel unbalanced and fall over. Likewise, many people get nauseous on a boat or when reading in a car, because the perception of motion from your vision and your inability to “correct” for it by moving your body causes disorientation. This is also probably why closing your eyes on an amusement park ride may save you from losing your lunch unexpectedly! As a result, even things like gross motor coordination (large muscle tasks) and fine motor coordination (small muscle tasks like writing or threading a needle) can be adversely impacted by obstructed vision. The lack of accurate visual feedback prevents the brain from giving the proper instructions to the limbs, making motor tasks a real challenge.

Fortunately for most children, the complete loss of vision is rare. However, many more children cannot see clearly due to other eye problems. Kids may have their vision affected by their focal length (near sightedness or far-sightedness) or the ability to control the fine muscles in their eyes that help the eye focus properly (astigmatism, strabismus [cross-eyed] and amblyopia [lazy eye]). Many of these problems can be easily corrected if recognized early. It becomes very important for parents to try to correct “lazy eye” – an eye that might seem to focus off course – or cross-eyes – eyes that seem to focus inward towards the nose- in order to allow the child to fully develop depth perception and binocular vision. If these conditions are not corrected at a young age, the child may never have proper depth perception, which can lead to all sorts of misjudgments of their bodies in space, and cause accidents. If a child cannot use his or her eyes normally, vision does not develop properly and may even decrease. After the first nine years of life, the visual system is normally fully developed and usually cannot be changed.<sup>11</sup>

If children have undiagnosed or uncorrected vision problems, focusing, especially when trying to learn to read in early elementary school, can be problematic. It is important to note that although vision problems have not been identified as a cause of learning disabilities, they can certainly contribute to learning problems in school, if the blackboard or books cannot be seen clearly. Fortunately, most optometrists and ophthalmologists can now perform comprehensive eye exams in their office on very young children, even without much active cooperation and ability to identify letters or numbers on the child’s part.

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<sup>11</sup> American Academy of Ophthalmology,  
[http://www.medem.com/MedLB/article\\_detailb.cfm?article\\_ID=ZZZOO3DZF4C&sub\\_cat=117](http://www.medem.com/MedLB/article_detailb.cfm?article_ID=ZZZOO3DZF4C&sub_cat=117).

Early vision correction with glasses, or with surgery if necessary to correct eye muscle problems, may prevent more severe vision problems and even improve performance in school. As a parent, it may be difficult to identify eye problems, since we cannot see through our child's eyes. To kids, their vision will always seem okay, since it is the only vision they have ever had, and they have no comparison point. We had an example of this kind of transformation with vision correction in our own home. Both of my children are farsighted, which is not easily diagnosed on the pediatrician's usual screening test, as these exams look primarily for near-sightedness. My kids sailed through the screenings, despite the fact that we later learned that our son, James, had a different focal length in each eye. The potential vision problem only came to our attention through observations from his kindergarten teacher. She had noticed that James took a long time to answer some questions on the board and to do some assignments at his seat – he seemed painfully slow. When we had his eyes examined, we were shocked to find out he needed glasses, and that this was totally missed on routine check-ups. After getting glasses, James's speed on tasks jumped dramatically, and he went from being the last one done in the classroom to often the first. Subsequently, we had our second son's eyes examined prior to entering kindergarten, and were equally shocked to find that he was seeing +5.00 in both eyes! While he could clearly read the smallest line on the chart at the doctor's office, print and pictures in books in front of him were just blurs. We joked he could read the date on a coin at 50 yards, but could not see his own fingers clearly, and there were very few, if any, clues that his vision needed correcting. Glasses easily corrected both boys' vision, and I have become a huge advocate of pre-school comprehensive vision testing as a result.

## **Hearing**

Unlike vision, hearing can be affected in a more broad-spectrum way. While we seem to have more time to identify vision problems and correct them, hearing for good speech and language development is vital. Around age 2, children are beginning to speak clearly and learn to communicate, so good hearing is vital. A hearing deficit will impair a child from learning how to repeat sounds accurately, as well as coordinate all the muscles required to produce those sounds.

While we measure the ability to hear by trying to determine what range of sounds (high to low pitch) and what intensity (loud to soft) people can detect, even mild hearing loss as a youngster can effect a child's development of oral language and speech. Besides mere volume and pitch, the clarity or "focus" of sound is also important, to hear many of the more subtle cues from our environment. Kids must simultaneously develop the ability to attend to certain sounds, while filtering out other noise as background or unimportant.

According to the American Academy of Otolaryngology, there is a six year window from birth to age 6 for children to develop oral language, in which hearing accurately plays a critical part.<sup>12</sup> Ear infections, common in young children, are also

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<sup>12</sup>American Academy of [http://www.entnet.org/healthinfo/hearing/hearing\\_loss\\_intervention.cfm](http://www.entnet.org/healthinfo/hearing/hearing_loss_intervention.cfm)

cited by the Academy as the most common cause of hearing loss in children, which can, in turn, delay their speech and language development.

In the PBS Series, “The Secret Life of The Brain,”<sup>13</sup> researchers discuss their findings in ongoing research about how children acquire language. At birth, children are referred to as “Citizens of the world” and their brains can learn any language, but as early as age 11 months, children have already begun to have their brains “wired” for the main language of their family and country, and do not hear the same fine distinctions in speech sounds that they could perceive just several months earlier. Obviously, this fast pace of development and acquisition of language skills requires that the main sensory input device for hearing, our ears, be operating as well as possible.

In the English language, we have 44 phonemes, or sounds, that make up our oral language. In order to speak, we must coordinate not only the precise movements of our tongue, cheeks and facial muscles, but we must also control the rate air passes over our vocal chords, adjusting it for tone, volume, and intonation, all of which we use in addition to the actual words to understand and communicate meaning to others. Hearing the subtle, softer sounds in speech and being able to reproduce them effectively is critical. Think about how things like humor, sarcasm, sadness, and joy are communicated through variations in tone, even when the exact same words are spoken. These subtle variations in speech production can drastically impact meaning. If a child is unable to perceive these variations, the comprehension of *what* is said, along with the shades of meaning delivered by *how* is said, will be lost.

Consider what happens when the ability to accurately alter your vocal tones is impaired, even temporarily, when you have a cold, sore throat, or even lose your voice. Because mucous around the vocal chords prevents them from moving freely, we can sound hoarse and are unable to maintain our usual range of vocal inflections. When this happens at my house, my husband might think I am unhappy or not as enthusiastic as normal, when in fact I am just temporarily unable to deliver my full range of meaning just by altering my voice. Likewise, if a child cannot coordinate all the equipment necessary to produce intelligible speech, their ability to effectively communicate will be impaired.

Concurrently, if a child cannot hear all the sounds of speech clearly, they will not be able to reproduce them clearly. The connections that need to be made between the brain and oral motor muscles and the ability to coordinate these muscles effectively rely in part on the feedback we get from our ears. Just think what happens if someone is talking to you and you have on headphones. Almost always, people initially speak loudly or yell at the other person, because the input from the headphones supplies the brain with the message “There is a lot of background noise, and I must speak loudly to be heard over it”, so our speech output is much louder than normal. If you take off the headphones, the background interference is gone, we can hear ourselves talking, and will automatically modulate our volume and tone accordingly. Likewise, the regulation of volume to meet

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<sup>13</sup> DVD and Video of the series, and the associated book and website are available at [www.pbs.org/wnet/brain](http://www.pbs.org/wnet/brain). Copyright 2001 Thirteen/WNET New York.



surrounding social cues, like yelling to be heard at a football game or party, or in contrast, not talking above a whisper in church or at the library, depends on being able to adjust the complex requirements of speech to the feedback we get from our ears and our cognitive centers.

While a good deal of experience is often required to learn the ins and outs of how any one person feels by listening to their speech patterns and inflections, people within a family often become very adept at this skill with each other. If a child has a hearing impairment, or cannot read these subtle cues about what is happening around him, he will miss the verbal tone warnings when, for example, Mom is becoming frustrated and upset – these just fly right on by. The child is then shocked when Mom “loses it” and gets angry, because the child did not get or perceive the vocal warning signs that trouble was clearly on the horizon.

In a domino effect, the inability to hear the subtle differences in speech can impact written language, when learning how to read, spell, and write depend on being able to hear the variations in sound and place them in specific order to form words and sentences. For example, we all sound different with a head cold, and speech sounds, received and expressed, are not as clear as they are normally. Spelling “I have a stuffy nose” for a beginner with a head cold might be spelled phonetically “I hab a stuvvy node” because the interaction between the ears and speech production centers tell them this is the sounds those letters make together at that point in time. The ability to translate sounds into letters and words are all interdependent with both speech and hearing. Spelling accurately depends in part by being able to sound out words yourself, and then process what letters go together to make these sounds. If you cannot hear these individual sounds, or if you cannot accurately reproduce the sounds yourself, it becomes much more difficult to master the whole concept of phonics while learning to read and write.

If hearing impairment is not detected early, the child may have to undergo intensive speech therapy to be able to correct annunciation and learn to pronounce the sounds well. It is critical for a child to be able to make themselves understood by others, and to accurately express themselves. When a child is just learning to speak, they begin with single words, mostly nouns, used in isolation, like “book” or “juice” or “mama”. It is common for family members to better understand a child’s initial speech than outsiders who may not get that “boo” means “book”. As children continue to develop, we naturally expect their speech to “clear” and that they will gradually begin to be understood by the outside world as well. The general developmental rule is that at 2, 50% of a child’s speech will be understood by strangers, 75% by age 3, and 100% by age 5. If this seems not to be the case, intervention with a hearing and speech specialist should be sought.

Likewise, prolonged hearing impairment may necessitate language therapy to help a child relearn, or catch up with things like grammar, intonation, and vocalization. Children with language disorders can have problems when learning to express themselves orally or in writing, because often the “gears” in the mind can work faster than the

communication apparatus, and thoughts can come out in a big, mis-ordered, jumble, missing key information that will help them be understood by others. Sentences may be overly simple and concrete, and not contain all the information we need to understand what has prompted this rush of information. While study skills and language therapy can improve these skills over time, it can be incredibly frustrating for the child to be repeating themselves, told to always slow down, and feeling unable to communicate all their thought and emotions even to those they love most, let alone the frustration they will suffer at school.

If a child loses part of their hearing, hearing aids can be used to make things louder for the child, and easier to hear, but background noise will likewise be amplified, but the clarity of the sound itself may not improve. The lack of clarity will make it more difficult to learn to produce speech accurately, and to making discriminations between certain key phonemic sounds, impacting the acquisition of reading and writing skills.

The surprisingly subtle nature of hearing and its feedback to our brains that allows us to produce speech and language so naturally, will, in turn, affect a child's ability to perceive language and express themselves with language. While not definitively proven, Expressive and Receptive Language Disorders seem to be logically impacted and even driven by the ability or inability to listen and reproduce sounds. Central Auditory Processing Disorder, a learning disability that affects the ability to comprehend or make sense of what is heard, is very difficult for children, because it delays their reactions to auditory information and instructions, even when the "data" is being communicated perfectly to the brain by the ears. Both of these learning disabilities may be partially attributed to whether the sense of hearing or its perceptive framework within the auditory centers of the brain is working as it should.

## **The Other Senses: Smell, Taste and Touch**

Smell, taste and touch sometimes get left behind as "less important" than vision and hearing, as key aspects of input to the brain about our environment. However, they have vital roles in giving our brains information about our bodies and what actions should be taken in response to stimuli, and they are powerfully tied to the emotion centers in the brain.

### **Taste and Smell**

Taste and smell are some of our more "primitive" functions, located closer to our brain stems in a part of the brain called the amigdala. This area of the brain is also responsible for our "flight or fight" response, mood, and other emotional reactions, helping to form powerful automatic responses. The powerful association smell, taste and touch have with emotion also help us encode things in our memory unlike vision and hearing.

For example, the smell of a pumpkin pie can take you back to your grandma's kitchen when you were only four; the smell of your garden after a fresh rain in the spring can remind you of days at summer camp; or the taste of fresh lemonade reminds you of

the time you and a friend drank all the lemonade from your first attempt at the sales business at the base of your driveway as a kid. Parents love to smell their children, and recent research has shown liking the smell of your partner is an indicator of the strength of your emotional bond. Whole industries have grown up to manipulate our senses and emotions, from perfume manufacturers to the recent boom of aromatherapies. Some people, such as professional actors, become very adept at summoning these sensations and their related emotional responses on cue, so that in the moment, their “acting” tears are not faked, but real, and they are actually experiencing the emotions they are portraying on stage, including all of the physiological changes necessary to produce and relive that moment, time and again. This is perhaps the ultimate ability to “get in touch with your emotions”.

Taste and smell are equally important to survival. If you cannot taste or smell “off flavors” in food, you might eat something that is harmful and could kill you. Manufacturers of household chemicals try to make sure that they have noxious flavors to prevent accidental ingestion by children, unlike those that make various medicines for infants, that add attractive flavors to get the child to ingest what they need. For a lucky few, a well-developed sense of taste and smell and the ability to make fine distinctions between subtle flavors can even lead to careers as restaurant critics, ice cream tasters, or wine experts as adults.

## **Touch**

Touch is a complex sense. Nerve endings all over our body can sense temperature, texture, and pain, and give us vital information about our body’s location in space. Through the early experiments by Harlow with primates discussed previously, we know how important loving touch can be for the proper emotional and physical development of children. Children who are not held can fail to thrive, and even die. Even as adults, touch is an important indicator of an emotional bond, both within families and in the outside world. Lyndon Johnson, for example, was well known for using a pat on the back and his handshake to help persuade the political opposition. Patient’s opinion of their physician is formed by the kind of touch they receive during an exam. Research has also shown that a gentle hand on the back or arm of a customer by a waiter or waitress can increase the tips left at the end of a meal. Adults who grew up in non-touchy homes can be heard to lament that they never received hugs from their parents. And of course, refusing to shake hands during or after a sporting event is considered the ultimate dismissal of the importance of another person. Touch is very clearly a message of acceptance and approval that runs through our culture.

Interestingly, taste, smell and touch are also the senses that can become de-sensitized over time as well. On first encountering a new smell, the nose can detect chemical messages in minute quantities. However, within fifteen minutes, we no longer can smell the scent with the same intensity or accuracy as before. Likewise, the first bite of a delicious meal may seem like nirvana, but by the end of dinner, it no longer tastes new and novel.

With touch, the same thing happens over time. For example, when you put on your clothes in the morning, your touch receptors feel every fiber and weave of the cloth, but rapidly, the excitement of those nerve endings are tuned out by your brain as “background noise”. Likewise, our sense of touch measures temperature and humidity, and we can accommodate to the surrounding climate and atmospheric conditions over time. When you go outside on a cold day, it may be shocking at first, but over time, it does not seem so cold. Likewise, people can move from colder to warmer environments, and eventually their bodies will adapt to the new climate. For example, I grew up in Upstate New York, but lived in Florida for some time. After about six months in Florida, I became totally comfortable with the high humidity and high temperatures, although at first it seemed unbearable. After this period of accommodation, I had a shock and trouble adjusting when going home for visits, where the cold outside and dry heat indoors made it hard to even breathe, after having adapted to an almost 95% humidity climate.

This period of desensitization, or accommodation and adaptation to new environments and stimuli is clearly vital to our functioning. Our brains need to learn to “ignore” certain pervasive background sensations, and to pay attention to the new and novel introductions into the environment. For survival and “optimal performance”, we need to be able to learn what demands our attention, and what is already safe and can be ignored. For example, a new sensation in our environment can be positive, neutral or a threat. When our senses become excited by new stimuli, we investigate them, determine how it needs to be addressed, and then after any action, it becomes part of the backdrop of our lives again. When we smell dinner in the oven, this means we need to start getting ready to eat, but when we smell smoke, a different set of actions is clearly required. (Either call the fire department, or plan on going out for dinner!)

With the strong emotional link smell, taste and touch have to the well being of children and adults alike, what happens if that system is not working properly?

## **Sensory Overload**

We can all become victims of “sensory overload” from time to time. It seems as if we all have a certain amount of stimulation we can take before we need to reset our circuits and prepare to receive more information from any of our senses. Because the senses are also strongly associated with the emotional centers in the brain, sensory overload can quickly lead to emotional outbursts that may seem surprising to everyone. Without an ability to “reset” our attention, like rebooting the computer, we will no longer be able to focus as needed. For example, long haul truck drivers can become victims of “highway hypnosis”, where they can fall asleep at the wheel, or simply not notice other cars on the road, from lack of novel visual stimulation over time.

Similarly, there seems to be an approximate time limit in which we can sit still and learn or work at our peak. After this time, our senses begin to deaden, and we can lose our train of thought, become sleepy, or otherwise begin to tune out the information we trying to absorb. In the real world, we build in breaks to allow us to be able to work and absorb new information more efficiently, before we reach overload. These breaks

are better known as recess to our children, and coffee breaks for adults. For example, most conferences and business meetings will have a schedule allowing for a coffee break mid-morning, lunch about an hour and a half or so later, a mid-afternoon break, and then close, all at about ninety minute intervals. Why is this? It turns out that for optimal learning and acquiring information, the brain needs time to consolidate information and “pack it” for future use. If too much information or stimulus is received, a lot of it will simply not be transferred into long term memory.

Likewise, too much environmental stimulus will begin to make people irritable and angry, or even cause them to shut down completely and sleep. Without a break, or a way to reset our stimulus thresholds, we will begin to react emotionally. For example, infants will initially cry and then fall asleep in very noisy environments- their brains simply require them to totally shut down and avoid stimulation they can no longer handle. Kids get irritable at the end of the day, mostly because they have had all the stimulation they can take, and they simply need to rest and regroup. Moms will often try to multi-task in the evenings, making dinner and lunches, talking on the phone, and managing kid homework at the same time. In our house, there comes a threshold at which any additional interruption from my children sends me over the edge, and I become angry or more irritated at their questions than I normally would be. This over-reaction is due to the fact that I can no longer adequately process all the stimuli I am receiving, and I snap, because that tiny, additional interference with my ability to process information sends the whole task-balancing act to the ground. It isn't the child's fault, it is mine, and simply due to over-stimulation. Likewise, we have all had hard days at the job or at home, where at the end of the day, you are simply emotionally and physically exhausted, even if you did not do that much physical work. Our ability to handle all the information our brains have received during the day has been used up, and we just want to rest and sleep, in order to be able to reset our “stimulus clocks” to prepare for another onslaught the next day.

### **Families and Managing Overload**

Most of the moms I know make sure they have ample amounts of snacks in the back of the minivan at any given time, because this opportunity to nutritionally recharge our kids prevents a lot of emotional tumult, and avoiding the “crankies” keeps the rest of our routine functioning well. We provide play time or breaks in the middle of homework, to allow our kids to be able to go to the next task refreshed and better able to concentrate and focus. In fact, the whole purpose of “time-outs” in discipline is to take a child out of a situation where they are receiving positive feedback (laughter from friends, getting attention) for negative actions, and remove this “reward”. We are, in essence, recognizing our kids have reached sensory overload, are reacting to it strongly, and we remove them from their current environment to try to reset their stimulation clock to zero. These are basic things we all do when raising kids, but they work because they allow the brain a rest to consolidate information and get ready to receive new input effectively again, much like saving a document on your hard drive. Without this opportunity to consolidate information, it won't be there to use later, just as all of us have experienced

when forgetting to save some critical piece of work before the computer crashed unexpectedly.

## **Sensory Problems**

For most people, our sensory systems have a sense of fatigue, where new sensations become less intense over time, as described previously. What would happen if our sensory systems did not have this sense of “desensitization” or accommodation? Primarily, our nervous systems would be much more aware on an ongoing basis of all incoming stimuli. This cascade of constant neuronal information would simply overload our brains, distracting us from other tasks and inhibiting our abilities to concentrate and function. To various degrees, there are individuals and children who have this sensory dysfunction, where their nervous systems do not seem to fatigue over time, and each sensation is as intense as it was when first encountered. For example, people with sensory problems may have a hard time differentiating between background noise from the air conditioner, and the teacher in the front of the classroom- both may seem equally loud to them. People with chemical sensitivities may always smell a moderate amount of perfume as if it were coming right out of the bottle, rather than accommodating to the smell after a short period of time. The intensity of the input may always remain high, and their systems may not be able to take the constant “shock” or stimulus it is receiving.

So what happens when a child has a problem with their sensory apparatus? In some children, the input sensory systems may all be working properly, but for some reason, the perception of the stimulus seems magnified. These children seem abnormally tense – sounds seem to always be too loud for them, smells make them crazy, tags in the back of clothing are distracting and uncomfortable, they tend to eat an abnormally restricted number of foods and be sensitive to textures, and even can be sensitive to light. While everyone may have some select sensitivities to certain types of stimuli, some children find almost all sensory stimulation to be like a lightening bolt of electricity through their system. There is quite a bit on controversy about whether such children have Sensory Integration Disorder, first described in the 1970’s, or fit somewhere along the Autism Spectrum Disorders, which include classic autism, high functioning autism, childhood disintegrative disorder, Rett syndrome, pervasive developmental delay, and Asperger’s Syndrome. Significant research is being done to better understand the causes of these disorders, which can have devastating effects on children and their families.

Sensory Integration Dysfunction (SID) was first described by Dr. Jean Ayers, a physical therapist, as an inability for a child to integrate the sensory information they were receiving and have it make sense, especially as it applied to motor planning. This means a child with sensory integration issues, for example, did not seem to be getting accurate feedback from their fingers about their position in space, and may be unable to coordinate visual information about letter shape in such a way to then be able to coordinate those fine motor distal muscles in such a way to be able to manipulate writing implements well, making handwriting very difficult. Children can have large motor issues, including walking, running skipping, climbing- all of which involve advanced motor planning- often referred to as coordination. Fine motor issues, in contrast, usually

show up as problems in lacing shoes, doing buttons, writing, and manipulating small objects. These problems can cause kids to be clumsier than their peers, have difficulty participating in sports and gross motor activities that are otherwise age-appropriate, have terrible handwriting, and even avoid doing things like lace their shoes. Kids may have balance problems that can make bike riding difficult. These motor issues, often accompanied by extreme sensitivity to sensory input from vision, hearing, taste, smell and/or touch, led Dr. Ayers to suspect the neural coordination of sensory information had gone awry. She recommended all sorts of physical therapy treatment to try to improve coordination and motor planning as well as desensitize children to stimuli so they could better function in their environment.

Since many children with extreme sensory issues have many features in common with children diagnosed with Autism Spectrum Disorders, including Pervasive Developmental Delay and Asperger's Syndrome, some people are beginning to believe sensory integration issues belong somewhere on the autism spectrum. In fact, most of the issues described by Dr. Ayers as symptoms of sensory integration dysfunction, are emerging issues of children along the autism spectrum. Recently, both Time Magazine and Newsweek have done extensive stories about autism and its related disorders. A number of the therapies used for autistic children such as touch de-sensitivity are similar to those used for SID. The interplay between sensory sensitivity and fine and gross motor delay in each group of kids, and sensory integration therapies that have been successful in treating children in both groups, seems to indicate significant overlap in the conditions.<sup>14</sup>

One of the symptoms kids with SID have in common with many of the autism spectrum disorders is a hypersensitivity to touch. Many autistic children do not like being touched and have significant issues with clothing, especially tags in their shirts and pants. They may be extremely sensitive to sound. They seem to have a heightened sensitivity to smells and tastes, leading them to have very picky eating habits, often based on textures. Some of the best information we have on what it is like to be autistic comes from Dr. Temple Grandin, an autistic adult who has been outspoken about her autism.<sup>15</sup> Dr. Temple describes wanting the comfort of touch, but that the touch itself was so over-stimulating for her nervous system, it was overwhelming. Touch became something to be avoided for its lightening-type effect, rather than fear or anger at the person doing the touching. Tactile therapy to desensitize the nervous system in both sensory integration disorder children and those with autism spectrum disorders may be helpful, even increasing eye contact and improving speech from her viewpoint.<sup>16</sup>

Since touch is one of the many things we use as part of our social bonding, many children with autism spectrum disorders and sensory integration problems have secondary social skill problems. Besides often being “non-cuddly” children at home with their families, these kids are no less touch-adverse with their peers. People touching them or bumping into them may cause them to over-react. Affected kids are often

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<sup>14</sup> <http://www.coping.org/copingbook/autism.htm>

<sup>15</sup> <http://www.autism.org/temple/visual.html>

<sup>16</sup> Id.

worried about noises that are too loud, making gym class, or going bowling with friends difficult, if not impossible. Their overall sensitivity to stimulus may make them very cautious about any new situation, and they may become very risk-averse.

As a result of avoiding sensory-overload experiences, these kids often miss out on many group activities,. They tend to lag well behind their peers in identifying the emotions of others, also being less likely to be able to accurately predict how others kids will react. Lack of social experience, along with the constant bombardment of sensory stimuli, makes these kids even less likely to have spent significant time observing others. They have not studied how people act, watched body language, tone differences, looks, and the more subtle aspects of human behavior which most people take for granted.

Imagine what it must be like to be a child with sensory problems. Not knowing many of the silent social cues we get about whether we “fit in”, or the appropriateness of our behavior and dress for the surroundings, also means not knowing how to correct for social awkwardness. The chances that the child will be picked on by their peers, not picked for teams, or otherwise have difficulty making friends goes up exponentially. These children often want friends, but they have few skills that let them make and keep close friends. They often end up feeling excluded and become even more resistant to trying new social situations, creating a negative feedback loop that is hard to break. This can be the most difficult disability for kids, as school and most employment opportunities later in life depend on being able to interact with others in social settings as well as the purely academic.

It is important to note while there are many speculations about the cause of autism and its related disorders, there has not been any definitive evidence laying blame on any one environmental, medical or developmental issue. New research shows that children with autism have higher than normal synaptic densities, meaning an overall higher count of connections between brain cells than normal kids, but it is unclear why this happens.<sup>17</sup> It does make sense however, that the sensory pathways in the brain of these children are somehow oversensitive, just based on the number of synaptic connections alone. Their perception of sensory information as much more intense than for most kids may be due, at least in part, to this higher number of nerve-to nerve connections.

### **Applying Brain Development Information**

Information on how the brain develops, and where it can go awry can be fascinating, but how does this apply in the real world, to real children? Unfortunately, we are just really beginning to understand the brain, and it will probably be many years before education fully develops teaching techniques that are mindful of brain development. Clearly, early sensory experiences drive physical brain development and neuron- to -neuron connections. This concrete, building block approach does allow parents to infer that:

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<sup>17</sup> When Does Autism Start? Newsweek magazine, February 28, 2005.



- a. The brain does a significant amount of its development and growth after birth.
- b. The more positive environment we can provide for our child, the better for their overall development.
- c. Cognitive development, or the development of thinking and learning will certainly be affected by the sensory information received by the child.
- d. If the sensory information the child's brain receives is impaired, the optimal cognitive development may likewise be impaired.
- e. Since the brain has a large capacity for change and plasticity, it can learn to accommodate new information and adapt, but early deprivation of sensory input may have long term consequences that are hard to reverse.
- f. Early intervention for any problem involving sensory input, especially vision and hearing, will be helpful in reducing any possible compromise in the child's development.
- g. Taking a "wait and see" posture to sensory input problems may be more detrimental long term than erring on the side of caution and over- treating a problem.

### **Parental Pointers**

- Parents should be particularly careful to make sure their children can see well; this may mean a visit to an eye care specialist, as the screening tests given in pediatric offices and schools may overlook some vision problems.
- Parents should make sure their children hear well. This means not only hearing the loudness and softness of sound, but also hearing clearly. Ear infections can leave fluid in the eustacean tubes and ear canal, diminishing the acuity of the sound heard, having a potential affect on speech and language development.
- Speech and language development is complex, and has a direct bearing on the eventual acquisition and development of reading and writing skills.
- If there seems to be any delay in speech or language development, early intervention is key. The sooner a child's problems are diagnosed and addressed, the less adverse affect they will have on his long term development.
- If a child seems particularly sensitive to noise, light, touch, or smells, this may be a sign of a more serious problem, and should be watched carefully.
- Certain labels of "syndrome" "disease" "disorder" and "disability" can be frightening. It is your job as a parent to worry less about any early "label" and worry more about your child on a holistic basis.
- Do be aware that we are probably limited in some ways by our "wiring". As a result, there may be some problems that cannot be "fixed" or "cured", but just worked around or accommodated.
- The development of the information highways in the brain are certainly driven in part by stimulus received from the environment. The cognitive, or thinking, parts of the brain will be shaped through both these environmental factors, and the interior thinking and reacting to these experiences that happens over time.

Cognitive development occurs in parallel with neural development, and it may often be difficult to tease out what problems are truly neurology based, and which are cognitively based. This can make understanding the thinking and learning process very difficult, as we begin to try to figure out where the roots and causes of learning differences lay.

# Cognitive Development of Children

## Beyond the Neurons: Cognitive Development of Children and Learning

As we look at how intelligence, cognition and learning develop in children, we need to keep in mind that on the microscopic level, we are talking about the gradual process of brain development and neuronal inter-connections. Once a child is born, their brains begin to grow rapidly. The infant is starting to become “hard wired” as their brain circuitry evolves, as their neurons begin to make their multiple connections in the brain, creating efficient information highways. Simultaneously, they are developing the “software” or cognitive framework, into which they will place all the information they begin to acquire about their world.

At this point in time, we cannot say for sure what causes learning differences or disabilities. Scientists and researchers are constantly finding out new information about the brain and its wiring, and how all of this may apply to development. Unfortunately, this means completely understanding all aspects of a child’s cognitive development is impossible at this time, as the story changes daily! In this section, we will try to give you an overview of cognitive development as we know it, and how thinking and learning develop. Hopefully, it will help you understand the different stages of development, why kids don’t think like adults, and help you put your child’s development in perspective. We will mention some basic cognitive psychology principals that effect the way people operate, as they will become very important later on in the chapter on Managing Learning Disabilities- A User’s Guide.

## Developmental Windows

The “windows of opportunity” described for the various sensory systems in the brain are mirrored in cognitive development, where certain skills seem to be more easily acquired during certain time frames. After these windows “close”, the skills may still be learned, however, they take much more effort and persistence to master. For example, the ability to master a second language is much easier if introduced before puberty. While adults can certainly learn another language, it is much more difficult than if introduced earlier. In fact, if you are introduced to a new language before puberty, chances are greater that you can learn to speak not only fluently, but without noticeable accent. Perhaps the best example of this is Arnold Schwarzenegger. The Governor of California is certainly fluent in English, but he retains his Austrian accent. Born in Austria in 1947, Mr. Schwarzenegger did not come to America until 1968, at age 21.<sup>18</sup> The retaining of his accent despite more than 35 years of residency in this country is due, in part, because he was not immersed in an English speaking only environment until he was past puberty.

The end of a particular developmental window just means that some of the flexibility of the “hard wiring” of the brain has diminished. Sometimes, the window may

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<sup>18</sup> [www.about.com](http://www.about.com) Arnold Schwarzenegger bio.

not be easily re-opened at all. When discussing the senses, for example, deprivation of stimulation at certain times of development may foreclose the brain from ever processing the information correctly. In cognitive terms, the brain has become less plastic, or less flexible. As an example, if you have learned to tie your shoes, or spell a word one way, and then are taught another, it may take much longer to “re-learn” the task in the new way. Undoing learned behavior is much more complicated than the initial learning, as changing the initial wiring of the brain is a tough job. The old connections still are there, and it takes consistent effort to relearn a skill.

The best example of this may be handwriting. Penmanship and basic letter formation is taught in early elementary school. Handwriting requires orchestration of small, fine motor skills to match a “picture” of each letter in our heads. We progress from block printing, to upper and lower case letters, to cursive, and each are used in different ways in school. Eventually, for most people, the process of writing becomes an automatic motor-memory task- we needn’t actually think about how to make a certain letter, or how it may flow into the next, it just happens as we need it to. For those with less-legible handwriting, the “appropriate” or most efficient way to make a certain letter may not have been taught, or they have developed their own individualized style of letter formation. However, after about third grade, handwriting tends not to change a lot. While it may improve somewhat with practice and over time, the basic handwriting is “wired”. Interestingly enough, as adults, our handwriting often consists of a mix of cursive and block capitals, individualized to each of us, perhaps an example of our brains mixing the two forms of letter formation we learned while young.

The ability to quickly acquire certain skills at certain developmental ages and stages is receiving more scientific support, with the advent of functional imaging scanners and other devices that allow us to measure brain activity during tasks. When early psychologists began to study children, they noticed that they developed the ability to think in gradually more abstract ways over time, and at certain stages of their growth and development. The idea of stages of development can now be “confirmed” as we begin to find out that each of the originally proposed stages seems to correlate with actual changes in brain anatomy and structure.

For example, Helen Neville, at the University of Oregon, and her colleagues are studying how language works in the brain. They are looking at different pathways for the development of concepts like grammar and syntax, the ability to distinguish language sounds across various dialects, and the plasticity in the brain over time regarding language acquisition.<sup>19</sup> Her ongoing research has demonstrated that there are underlying physiological pathways involved in learning language, with time or developmentally sensitive windows during which the brain is more active and receptive to learning language. Likewise, we now know that the pre-frontal cortex of the brain undergoes a huge amount of growth during adolescence, and this period can continue into our early twenties. It is not surprising then that this area, largely responsible for critical thinking and judgment, is developing in connection with the increased level of abstract thinking

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<sup>19</sup>Neville, H Bavelier D.” Human Brain Plasticity: evidence from sensory deprivation and altered language experience.” *Prog Brain Res.* 2002:138:177-88.

required in high school and college courses. Similarly, our western ideas of adulthood correlate with the development of responsibility in the late teenage years. College, for many people, concludes when they are about twenty-two, the period at which their pre-frontal cortex development begins to conclude as well.

### **Positive or Negative – The Driving Force in Behavior**

How does all this happen? How do we evolve from infants to children to adolescents to adults, and how do we form our view of the world? The first “rule” so to speak, is that of Positive and Negative Reinforcement. In the 1970’s, psychology became dominated by a group called behaviorists. They believed that most human behavior could be explained by breaking things down into positive and negative experiences, and this feedback could help make human behavior more predictable. While it turns out that behavior is much more complex than this, positive and negative reinforcement are two of the most powerful tools for controlling behavior.

Simply put, positive reinforcement gives us pleasure and negative reinforcement gives us pain. In behaviorist terms, individuals will choose the positively reinforcing behavior over the negative, in order to gain a reward. An example of this is teaching a dog to sit. In order to get the dog to sit, you offer the dog a treat (a positive reward) when he sits down. After several trials, the dog understands that when you ask him to sit, and he does the behavior, he will receive a reward. Eventually, the dog will sit on command, whether a reward is offered or not. The behavior eventually becomes ingrained and becomes a part of the “operating system”, so to speak.

Positive rewards will reinforce behaviors, and will change them over the long run. Negative reinforcements, such as punishments, will cut off bad behavior, but do not work well in changing behavior. So if your kids are yelling, and you tell them to stop, they might. If they are punished for yelling, the yelling will stop- however, it may start right back up again, once the punishment is withdrawn. In order to cease yelling in the house all together, you have to reward the “not yelling”, which tends to be harder to do, and requires much more consistency. It is easier as a parent to dole out punishments to stop a bad behavior, but this is ineffective to really change the behavior all together.

In order to make a permanent change, a parent has to catch a child being good, and positively reinforce the good, not punish the bad. For example, a child running through the house, or hitting a sibling, will cause a fuss, and attention will be paid to the problem. Kids will be punished. However, catching a kid “not hitting” a sibling, and rewarding that behavior, is harder to do consistently. Simply, being good does not catch our attention the same way being “bad” will, but rewarding good will keep the good behavior going, and eventually the bad will die out.

The parental chestnut of the “time out” is a classic positive-negative reinforcement tool. The purpose of a time out, or “benching” a kid as a friend refers to it, is to remove a child from a situation where they are receiving positive reinforcement for negative behavior, like when they are kicking a door- the noise and feel can be positively

reinforcing for the action. By removing the kid from the area, they are no longer receiving the reinforcement, so you can change the behavior. Time out was never intended to be a punishment, but is to be used to isolate a child from this “positive” reward they are getting for behavior we think is less than great. It should just be a time for kids to regroup, and return to make better choices.

In developmental terms, positive and enriching experiences will encourage and stimulate brain connections, as will negative experiences. Positive experiences will encourage certain behaviors and stronger neural connections, while negative experiences will discourage behavior, and each will impact cognitive development.

All of a child’s early developmental experiences, positive or negative, will permanently alter the brain’s structure as it grows and develops. Likewise, they will impact the development of a person’s viewpoint and personality. As adults, when we blame some of our shortcomings on our environment as children, or on the parenting we received, part of this is very true. The development of our brain was guided and sculpted in part by our environment and our parents. However, our perception, interpretation, or viewpoint of these early experiences is an equal part of the picture of who we are as adults. This is primarily why early experiences with family, caregivers, and early childhood education are so critically important. The development of love, trust, sharing, caring, morals and values all begin with our earliest experiences with other people. If our parents are loving and caring, we will see this as a good thing. If our parents are indifferent to us as children, the chances that we will grow up to trust and count on other people to be there, is diminished. If our parents out and out dislike us, the chances that we will develop healthy views of relationships with others are pretty slim.

In our chapter on Behavior Management, we will discuss more in depth the role of positive and negative reinforcement in helping our kids to learn to make good choices as they learn to self-regulate their behavior. For now, just keep in mind that behavior is very complex, but the positive/negative reinforcement or transactional view of behavior is important in starting to understand how we learn to think.

As we explore the cognitive development of children, we therefore need to keep in mind that:

- The brain continues to develop until our early 20’s;
- Certain periods of time referred to as Developmental Windows are beginning to be recognized, where certain skills and ability to learn or understand essentially begin to come online.
- Once the developmental window has passed, it will be more difficult to acquire the missed skill.
- If a child is not yet developmentally ready to learn a skill, it is largely futile to try to get them to master it. If they do not yet have the brain power and cognitive skill to understand something, attempts to get them to master certain concepts may be futile. Expectations for academic and social achievement should keep these stages in mind.

## What Makes Us Smart?

Since the advent of thought and philosophy, people have wondered what differentiates humans from animals. What defines intelligence, and what is consciousness? The development of “cognition” or knowing has become a whole field within psychology, especially as it relates to the growth and development of children. Psychologists have debated whether development is shaped by maturation, changing responses to the environment over time, or driven by societal pressures. Regardless of the framework of the discussion, it is clear that the cognitive development in children proceeds in a pretty predictable way and seems to have identifiable stages and milestones.

For example, children born with club feet may spend a large part of the first year of life in casts. Despite this, many still start to walk around age one, regardless of their prior mobility problems. Why would a child be so driven to walk at this age, especially if they cannot move like “regular” kids? What motivates a child to need to walk at age one? Why do children start to lose their belief in Santa Claus at around age 7? Some of the answers to why children seem to go through specific stages in their understanding of the world can be found in the work of Jean Piaget. Piaget was the first person to note how people begin to develop cognitively over time through the study of children, and is considered by many to be the father of developmental psychology.

Jean Piaget began studying children while helping Alfred Binet develop the first IQ test in France in the 1920’s and 30’s. He noticed that younger children thought about problems and tasks in a completely different way from older children and adults, and that their perceptions changed as they grew older. Piaget was the first to have insight into how we begin to shape our behavior to our environment, and how this process changes and evolves as we age.

Piaget proposed that infants are born with reflexive responses to their environment, but that over time, these reflexive or innate responses are replaced with “assimilation and accommodation”. Unlike animals, Piaget proposed that humans adapt to their environment in more and more complex ways over time. By using **assimilation**, children use or transform their environment to fit into pre-existing mental frameworks. In contrast, **accommodation** requires changing the mental framework to accept new information from the environment. For example, an infant reflexively may suck a bottle; they will use this same process on all new things in their environment until they can sort out what responds positively to this behavior and what does not. They will suck on things that will provide food and those which will not, trying to assimilate the new item into their cognitive world. Over time, the infant will begin to sort out which items are not food, and therefore don’t really respond well to sucking; so instead of being assimilated into the “Things to Suck” category, they develop new ways to understand and use the new item, through accommodation. In this way, an infant begins to learn that a rattle for example, while pleasant to suck on, is really much more useful for making noise or getting Mom’s attention. Likewise, certain objects, like the dog, may provide a negative response, so the child probably won’t suck on that object again.

The process of assimilation and accommodation is repeated over and over, developing more complex behaviors over time as children age, and continues even with adults. For example, you may travel a specific route to work, every day. You have determined that this is the best route to take, or the easiest, through assimilation of all available information. However, if the route is disrupted by construction, you will need to develop an alternate route, leave home earlier, or otherwise alter your behavior quickly, by adapting to the current situation, and find alternatives that will still ensure you get to work on time. Adaptation to the situation at hand and changing behaviors to meet this change was one of the signs of human intelligence differentiating us from animals, as proposed by Piaget.

As children age, Piaget theorized that kids go through a number of stages. These stages, which have approximate ages associated with them, include:

**Sensory Motor Stage (infancy)** During this stage, children's knowledge of the world is based on their own personal interactions with it. Children acquire "object permanence", meaning that they begin to understand that an object will remain in place even when it can't be seen- at about seven months of age. Most people will remember that babies about this age love "Peek-a-boo", as it is confirming their new theory that even if they can't see an object or person, it is still there! As kids begin to move around on their own by crawling and walking, they likewise begin to develop more intellectual capabilities as their horizons begin to expand exponentially, to the joy and frustration of parents now chasing them everywhere.

**Pre-operational stage (Toddler and early childhood, until age 7)** In this period, memory and the use of language and symbols begin to develop quickly. Imagination develops, but thinking is non-logical, and non-reversible, meaning children don't really grasp that subtraction is the opposite of addition. Children have a hard time taking the place of others, and everything seems self-centered. For example, a kindergartener is still at the stage where Santa Claus, The Tooth Fairy, and other "magical" creatures are totally possible and real to them. In our family, my younger son wanted to go home and chase leprechauns in our neighborhood after a St. Patrick's Day celebration in kindergarten (he was five), and was not to be dissuaded. Likewise, it is not unusual for a child to see their first movie in a movie theater and not be able to understand why it can't be rewound or stopped when they want it to be. Cause and effect and the passage of time may still not be easily understood. For example, my younger son, now six, does not yet grasp the linear nature of time, and that if he is not quick about getting dressed in the morning, he will not have play time before he gets on the bus. He cannot yet fully grasp that there is a finite amount of time available, and his choices on how to spend his time will effect what he can or cannot do later on.

**Concrete Operational stage (elementary school through early adolescence, ages 7 through 11)** Kids begin to develop an enhanced, logical view of the world during this stage. They begin to understand that two glasses of different shapes can contain the exact same amount of fluid; they can begin to understand that a number of objects will remain the same no matter how they are ordered, and other similar "conservation" concepts,



critical with math skills. They begin to understand that certain things are reversible, such as addition and subtraction, or multiplication and division essentially being opposites. Kids also begin to develop the ability to understand things from another's point of view. Children begin to develop a better understanding of cause and effect and the passage of time that clearly is not present at an early age. It is not surprising that this is the time when belief in Santa and the Tooth Fairy begins to wane, and when children start to develop more friendships. Instead of "parallel play", where children essentially do something similar next to another child, kids start to really interact, play board games, and engage each other in interactive play and conversation.

Kids begin to be able to manipulate symbols and things easier in their minds, without having to rely on concrete objects for "proof". Kids begin to develop "mental folders" and begin to classify information on many levels, including subject, shape, size, color, or any other feature. For example, kids can begin to memorize math facts and do mental math. They can begin to note the similarity and differences between objects and begin to make some judgments about what may be better.

**Formal Operational Stage (adolescence into adulthood, ages 11 and up)** Kids begin to be able to think in more abstract terms. They can begin to think about the future, make predications and hypotheses, and can discuss ideological problems. Kids may begin to develop more varied interests, handle complex topics like "freedom" or "patriotism" and develop their own thought out, reasoned opinions. It is supposed that not everyone always acquires formal, operational thinking, or is required to use it in the course of their everyday lives.<sup>20</sup> This period and developmental stage is the time when concepts, ideas, and individual perceptions really start to take hold.

### **Piaget's Theories Today**

Interestingly, while many experts feel that Piaget's stages may be too rigidly defined, there is growing research that suggests changes in brain development at about the time when Piaget's stages change. For example, research has shown that learning becomes most efficient when the extremely rapid pace of brain growth begins to slow, at about age 7. This happens to be first grade age for most children, the time when we begin to ask them to sit, attend and learn, more so than at previous ages, and coincides with the Concrete Operational Stage. Certainly some children will arrive at certain stages before others, with age itself not being the sole factor in whether or not a child is capable of any particular skill. Likewise, the beginning of the Formal Operational Stage lines up with the transition from elementary school to Middle School and the beginning of adolescence, and the beginning of development of the pre-frontal cortex area of the brain. New research has shown that this area undergoes slow growth and change as children age, but that the most dramatic periods of change begin in early adolescence and

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<sup>20</sup>General Piaget stages taken and adapted from <http://chiron.valdosta.edu/whuitt/col/cogsys/piaget.html>. As Piaget is the best known developmental psychologist of the past Century, more information about the stages is widely available on the internet, as well as in any basic psychology textbook.

continuing until the early 20's.<sup>21</sup> This area of the brain is the center for critical thinking, judgment, empathy, organization and problem solving, among other executive functions. We now have MRI studies supporting that the physiological growth in the prefrontal cortex correlates and coincides with Piaget's Formal Operational Stage, where he hypothesized that children begin to develop abstract reasoning and problem solving capabilities at about age 11.

As parents and educators, we need to be aware of this cognitive developmental time line as we begin to ask kids to achieve academic goals earlier and earlier. At some point very soon, we will be asking kids to tackle academic subjects and concepts for which their brains are just not yet prepared, developmentally speaking. Whether cognitive development follows a strict timeline, a spectrum or has certain distinct leaps in insight and understanding, is largely an academic debate. It is important to realize that children do change dramatically over time as their brain and body grows. There are clearly certain stages in development where children are not capable of thinking like adults because they simply do not have the cognitive capacity to do so. We need to adjust our expectations of our kids accordingly.

Up until a few years ago, there was little research that supported Piaget's theories as anything but psychological and cognitive suppositions. Parents now have not only the theoretical models of cognitive psychology, but medically relevant data supporting the idea that adolescents are still developing their ability to reason. Since judgment and the ability to take a second look at a problem before acting is still developing physically as well as cognitively, parents should expect kids to make poor choices and need guidance well past the age where they begin to insist they "know it all". As Mark Twain once remarked, "When I was a boy of fourteen, my father was so ignorant I could hardly stand to have the old man around. But when I got to be twenty-one, I was astonished at how much the old man had learned in seven years."

### **Piaget Expanded- Dr. Mel Levine and Neurodevelopment in Kids**

Dr. Mel Levine, the premier Developmental-Behavioral pediatrician in the country, and well known author, has elaborated on Piaget's work and has proposed using "neurodevelopmental constructs" when looking at the individual talents and weaknesses of children. These constructs subdivide cognitive tasks like attention, memory, spatial and sequential ordering, social cognition, processing, and production into individual skill sets. Levine's models are extremely detailed, which make it easier to find out which specific areas of cognitive development may be slower to develop or even impaired in some children.

In kids with learning disabilities, for example, specific aspects of language development, memory or attention may be impaired. Levine and his colleagues Dr. Levine is an advocate for neurodevelopmental assessment of children, and in "demystification", a process in which the child is told specifically what his strengths and

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<sup>21</sup> Based on MRI studies of normal brain development by researchers at the National Institute of Mental Health, published online on 5/17/04. [http://www.eurekalert.org/pub\\_releases/2004-05/niom-iss051304.php](http://www.eurekalert.org/pub_releases/2004-05/niom-iss051304.php)

weaknesses are. By identifying the specific problematic areas, parents and the school may better be able to understand what a child is capable of doing. They may also provide information about how to harness a kid's strengths to help compensate and improve weaker skill sets. For example, a child may have a natural talent in math, but have trouble with writing. Levine might suggest allowing the child to work on constructing word problems for classmates, or research a famous mathematician as a way of using a child's natural interests as a hook to get them to improve their weaknesses over time. Dr. Levine's concept of "Islands of competence" suggests that parents help a child to find out what the child is good at, and what their interests are, in order to exploit these natural affinities to the child's overall benefit.

### **Cognitive vs. Associative Tasks**

Another important cognitive construct that is important for understanding kids, is the concept of associative or cognitive tasks.

Associative tasks are those which we can do automatically, without thinking. For example, when we brush our teeth in the morning, we do not really have to think about all the steps necessary to complete this chore- it happens by





Parental Pointers:

- ★ Cognitive development in children occurs in distinct stages.

When I was growing up, there were always kids in school who seemed brighter and "dumber" than the rest of the class. It was acceptable to be good at some things and bad at others. By contrast, in education today, we expect kids to be good at every subject and to excel, yet we don't emphasize the academic skills, strategies and tools kids need in order to meet these high expectations. For example, I was never formally taught or told how to study for a test – it was assumed you would figure it out on your own, or pay the consequences by getting a bad grade and getting yelled at by your folks. Because certain things came easily for me, my study habits were not exemplary by a long shot. Hit or

miss might be a flattering way to describe the trial and error method of test preparation I practiced, and despite this haphazard process, I managed to do quite well and get admitted to an Ivy league college, I am sure to the great surprise of some of my teachers. Today, my children face an education system in which performance on a specific test, on a specific day, will determine whether or not they will be able to advance into the next grade.

### **She notes these developmental milestones:**

-  **Permanent teeth emerge, physical coordination and control improves.**
-  **A sense of fairness, ethics and responsibility grows.**
-  **The imagination flourishes, but mental agility increases, too. A child in middle years can solve problems mentally, without the need of a hands-on process.**
-  **Individuality begins to emerge, although most children want to look and act like their friends. Friendships take on a new importance.**

**Diamond calls the middle years a "window of opportunity" for growth in reading, as well as music, athletics, math and other skills. The more books, poems and plays a child reads, for example, the thicker the speech area of the cerebral cortex becomes.**

Developmental research has shown that there are developmental windows of opportunity for different brain functions. Thus, the windows of opportunity for emotional development is 0-2 years, mathematics and logic is 0-4 years, language is 0-10 years, and music 3-10 years. These windows of opportunity if not utilized by parents and educators will lead to impairment or loss of the appropriate function.

Dr. Levine has started the All Kinds Of Minds Institute,<sup>22</sup> and a program called Schools Attuned, where he and his colleagues are working diligently to help schools and parents to recognize the diversity of abilities and talents each child has. They seek to adapt the learning environment so that it is more tolerant of this diversity. As a child goes through school, there will be times when their minds, or cognitive skills, do not always match up well with the demands in the classroom. Dr. Levine refers to kids whose minds do not appear to be good fits with their environment as having learning differences, rather than learning disabilities. The children can learn, and do learn, however, they do not always do it in the same way or at the same speed, as the rest of the classroom. This

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<sup>22</sup> More information about All Kinds Of Minds and learning differences can be found online at [www.allkindsofminds.org](http://www.allkindsofminds.org).

model recognizes that many kids conventionally labeled as “learning disabled” are very intelligent and often more so than many of the students in the classroom. However, they differ because their minds are wired so that they do not assimilate the information in the same way as the majority of students. These students may require, for example, a longer time to process information, need the volume of information given at one time adjusted, or be assisted in developing academic skills and strategies that allow them to adapt their strengths to aid their weaknesses.

Dr. Levine views self-esteem to be vital to a child’s success, and has stated “Success is a vitamin” that every kid needs to grow and thrive. This is particularly true for kids who struggle in school or at home, who get very few positive messages about themselves on a daily basis. As a result, rather than classifying student with specific learning disability labels or names, Levine advocates recognizing that all children can and will learn, if they are taught in a way that better recognizes their inherent cognitive strengths. The term “disability” is avoided, because it connotes that the child is somehow defective, or less able than his or her peers, when the opposite may be true. The child may have more inherent talents than others, but certain cognitive skills are slower to develop, placing the child at a significant disadvantage in the classroom.

While Dr. Levine’s work is very helpful to parents and educators in trying to identify specific areas of weakness in a student’s profile, it can also confuse as much as it clarifies. Programs in public schools are structured to identify struggling students and qualify them for services if the degree of impairment is severe enough. Specific diagnostic labels are required, just like the specific treatment codes a physician uses to ensure insurance coverage for treatment. While preschoolers are labeled “developmentally delayed” if they do not appear to be on track with developmental milestones, they magically become “learning disabled” once they hit kindergarten, with “learning difference” not being an option. While the underlying cause of the learning disability may be an active working memory problem along with poor mental energy controls, for example, the school cannot offer support for that diagnosis but needs “dyslexia” “ADD” “specific language disorder” or another “approved” label in order to get the child the assistance they require. While we will discuss the pros and cons of “the label” later on, having a name for whatever your child’s struggle may be can be immensely helpful. Besides providing a name or reason for the child’s issue, parents can use this diagnostic label to locate books, websites, support groups, and other information sources regarding kids and parents similarly situated. Without a name to call this “thing”, you may end up feeling isolated and have much more difficulty in locating resources.

For children, every new experience from the moment they are born provides sensory stimulus to the brain that drives its development and functioning. Smell, taste and touch are some of the most important “instinctual” sensory input we get as infants. These three senses help us begin to make emotional attachments to our parents, find nutrition, and begin to frame our world. Particularly since our vision is not clear at birth, and we haven’t had enough auditory input to really begin to differentiate sounds as language, music, or just background noise, for example, we are almost completely reliant on our smell, taste and touch to begin to make sense of our world. These early, highly

sensory experiences have been shown to be critical in whether or not we thrive as infants, and in turn, how we will turn out as older children and adults.

As our vision improves in infancy, we learn to focus and track object, and gradually our hearing begins to allow us to discriminate between the sounds of speech and background noise. Vision and hearing tend to take over and become more important in our perceptions of the world, as higher cortical functions of speech, language, and learning all begin to interact, rather than solely relying on our smell, taste, and touch as our primary means of experiencing the outside world.

## Brain Development and Stimulation

### Nature vs. Nurture

As scientists continue to try to understand how children acquire skills, and why some individuals do not, they are examining what early stimulation (or the lack thereof) does to the physical wiring of the brain and its cognitive function. If there is too much stimulation too early, will this “shock” the nervous system and lead to learning problems down the line? If there is not enough appropriate stimulation during childhood, can the child still be successful? Answers to these questions are still being sought, although progress towards understanding how the young brain grows is increasing daily. It is clear however, that input drives development in both positive and negative ways.

We know that the loving touch and nurturing of an infant leads to faster growth and happier infants. From early research on primates in the 1950's, a researcher named Harlow discovered that touch and physical comfort was as important as nutrition to the psychological development of primate infants. While this is a given today, these early psychology experiments were the first steps to try to find out how nurture, or the experiences a child has in their early life, affects, or even supercedes nature, the genetic gifts and predispositions we receive from our parents.

We are learning that while some infants may fail to thrive if they get too little stimulation after birth, too much stimulation, too soon, can be equally debilitating. For example, doctors take measurements of children at checkups to check for normal growth and development, but also for Failure to Thrive. This condition seems to be caused by stress in infants and ineffective nurturing, which can cause children not to eat and grow as expected, putting them at risk for developmental problems. Scientists are continuing to study how nurture affects all aspects of brain development, but it is clear that babies need touch and love as much as they need food and nutrition to develop well. In contrast to Failure to Thrive, which may be caused in part by too little environmental stimulation, we also know that too much stimulation can be debilitating for children.

Infants born prematurely are known to be at greater risk for a wide range of developmental problems and learning disabilities than full term infants. Researchers have found that by redesigning the Neonatal Intensive Care Units (“NICU”) in hospitals, they can reduce the number of developmental problems experienced later on. Since the brain is not yet fully developed at birth in full-term babies, for premature infants, the brain is even less ready to meet the outside world. Instead of the older, noisy, bright, and

jarring intensive care units that were similar to those for adults, premature infants are now being cared for in specially designed, low-sensory input environments. In the new NICUs, babies are protected from the huge amount of stimulus including light, sound, touch, and other stimuli they would normally begin to receive immediately after birth.<sup>23</sup> Low light conditions, quiet, soothing, gentle touch, and the like are used to reduce the stimulation the baby would otherwise encounter, in hopes that this will mimic the protected environment of the womb as closely as possible. By protecting premature infants from becoming overstimulated, Doctors are hoping to normalize brain development in premature infants and head off later developmental problems.

Stimulus clearly drives development, and we are learning that having too many brain cells may be just as debilitating as having too few. New studies are showing that in conditions like autism, the brain may grow too big, too quickly. While it is unclear why this brain overgrowth occurs, it is clear that children with autism spectrum disorders can have long term problems in functioning.

### **Exploring the Environment and Perception**

Unlike a computer, the brain's wiring continues to grow and change constantly in response to the environment. New connections are formed, and other less used pathways seem to wither and get "pruned" off the circuitry pathways. For children to develop well, they need input that is nurturing in the classic sense- it provides enrichment, protection, a feeling a safety and well being, and allows the child to learn effectively. The sense of touch is clearly important in a child's early exploration of the world, as they seek to touch everything, put things in their mouths, and otherwise explore their worlds. With each of these actions, the infant's brain is forming new connections and memories that will be with us for a lifetime.

### **The Senses**

Our brain receives information about the outside world through our five basic senses – Sight, hearing, touch, smell, and taste. This information is delivered as nerve signals from the sensory organs which our brain then interprets using our "cognitive processes" in order to make sense of the information delivered. Very much like a keyboard and mouse for a computer, the senses take the "input" from their source and then "process" or interpret this information in a useful way. If the data received from these sources is not accurate, or is not received at all, the processing of the information received will likewise be faulty and inaccurate. Likewise, if too much information is

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<sup>23</sup> The Secret Life of The Brain, Episode One "The Baby's Brain: Wider Than the Sky". PBS Video, 2000.

<sup>25</sup> As a side note, in the land of insurance coverage and treatment options, this is an example of a medical problem that would receive coverage under health insurance plans that then becomes a brain or psychological problem after the age of three. This means that treatment is no longer covered by most insurance plans, but is instead deferred to schools for treatment as a "developmental disorder", an educational or psychological classification.

received, it can overwhelm the ability of the brain to process the information, and cause the system to shut down.

The senses are also where the division between medicine and psychology begins. Most medical fields are oriented towards treating a disease or defect, so Ophthalmologists, for example, treat malfunctions of eyes, while Otolaryngologists (Ear Nose and Throat or ENT doctors) treat malfunctions in the ears, nose and throat systems. Like mechanics or computer technicians, their primary job is to fix the input or sensory devices only. Any subsequent problems of cognition, such as lack of depth perception in vision, or deficits in being able to express oneself through language, fall to different therapists, psychologists, and psychiatrists to sort out. Unfortunately, this is also why impairment of a primary “input” such as hearing, which clearly may delay a child’s speech, gets classified as “developmental delay”. A problem which has begun as a medical dysfunction, can turn into one that is classified as primarily psychological in nature.<sup>25</sup>

## **Vision**

Certain areas of our brain become specialized over time to interpreting specific kinds of information. For example, the visual cortex becomes very specialized in analyzing the information received from the eyes, identifying it, and allowing us to act on this data. Newborns see very indistinctly at first, and do not have binocular, three-dimension vision. After a few months, after significant “sorting” of neurons and feedback to ocular muscles regarding focusing and movement of the eyes, babies are able to follow objects, identify members of their family on sight, and really begin to use their vision as a tool to learn about their world. As you can imagine, if the information being transmitted to the brain from the eyes is not good due to a fault in the eye itself or its ability to focus, the brain will only process the fuzzy information it is being fed from its outside monitor of the world around.

If something deprives a child of early vision or early visual stimulus, they may never be able to see. In 2000, Michael May, a man blind from an accident at age three, had an operation to correct a defect in his eyes that prevented him from seeing.<sup>26</sup> Although his brain received nerve signals from his eyes, his visual cortex hadn’t received any information for over forty years. Since his brain learned about things mostly by touch, scientists were fascinated to see how this repair to his vision would affect him. Mr. May is one of the incredibly rare people who have had this kind of experience, and in essence, he has been forced to “relearn” how to see as an adult. He can see colors, and motion, but recognizing faces, including that of his wife, requires additional cues from the environment, like hair color and length. Mr. May has said he has gotten better at guessing these things over the past few years, but he still feels as if he is guessing about many of the things he sees. He describes his vision as being like walking into an abstract

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<sup>26</sup> NPR, Morning Edition, August 23, 2004, interview with Michael May; NPR Talk of the Nation Science Friday, August 26, 2003, Interview with Ione Fine, Assistant Professor, Ophthalmology, Doheny Eye Institute, Keck School of Medicine, University of Southern California, Los Angeles, California.



painting, with many colors and movement, but the clarity and distinctness of images is largely absent.

Similarly, people who have been blind from birth may never be fully able to interpret the “visual noise” they will see if their vision is restored. For example, a project being run through the Massachusetts Institute of Technology is helping to restore the sight of many children with cataracts in India. The MIT group has found the restoration of vision is most successful when done early.<sup>27</sup> The later in life the corrective surgery is done, the more severe the reaction can be for the patient who can now see a world that was formerly dark and isolating. Many of the older patients have developed depression, or simply decided it was easier for them to function day to day by continuing to act blind and not use their eyes. This is probably due to the fact that the brain has never had the opportunity to learn how to cognitively interpret the images that have been restored to them. Even though the “input” from their visual system is functioning perfectly, the amount of information is simply overwhelming and simply overloads their circuits.

Vision is not isolated from our other senses. Vision allows us not only to locate objects in space, but helps us to sense things like speed, motion, perspective, distance and the like. For example, balance and coordination can be affected by vision. If you try to balance on one foot, it is much easier to do if you have your eyes open and focus on a point in space. If you close your eyes, you no longer have the feedback from your vision about where you are in space, and can quickly feel unbalanced and fall over. Likewise, many people get nauseous on a boat or when reading in a car, because the perception of motion from your vision and your inability to “correct” for it by moving your body causes disorientation. This is also probably why closing your eyes on an amusement park ride may save you from losing your lunch unexpectedly! As a result, even things like gross motor coordination (large muscle tasks) and fine motor coordination (small muscle tasks like writing or threading a needle) can be adversely impacted by obstructed vision. The lack of accurate visual feedback prevents the brain from giving the proper instructions to the limbs, making motor tasks a real challenge.

Fortunately for most children, the complete loss of vision is rare. However, many more children cannot see clearly due to other eye problems. Kids may have their vision affected by their focal length (near sightedness or far-sightedness) or the ability to control the fine muscles in their eyes that help the eye focus properly (astigmatism, strabismus [cross-eyed] and amblyopia [lazy eye]). Many of these problems can be easily corrected if recognized early. It becomes very important for parents to try to correct “lazy eye” – an eye that might seem to focus off course – or cross-eyes – eyes that seem to focus inward towards the nose- in order to allow the child to fully develop depth perception and binocular vision. If these conditions are not corrected at a young age, the child may never have proper depth perception, which can lead to all sorts of misjudgments of their bodies in space, and cause accidents. If a child cannot use his or her eyes normally, vision

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<sup>27</sup> “Sight Unseen”, Massachusetts Institute of Technology News Office, August 25, 2003  
<http://web.mit.edu/newsoffice/2003/sinha.html>.

does not develop properly and may even decrease. After the first nine years of life, the visual system is normally fully developed and usually cannot be changed.<sup>28</sup>

If children have undiagnosed or uncorrected vision problems, focusing, especially when trying to learn to read in early elementary school, can be problematic. It is important to note that although vision problems have not been identified as a cause of learning disabilities, they can certainly contribute to learning problems in school, if the blackboard or books cannot be seen clearly. Fortunately, most optometrists and ophthalmologists can now perform comprehensive eye exams in their office on very young children, even without much active cooperation and ability to identify letters or numbers on the child's part.

Early vision correction with glasses, or with surgery if necessary to correct eye muscle problems, may prevent more severe vision problems and even improve performance in school. As a parent, it may be difficult to identify eye problems, since we cannot see through our child's eyes. To kids, their vision will always seem okay, since it is the only vision they have ever had, and they have no comparison point. We had an example of this kind of transformation with vision correction in our own home. Both of my children are farsighted, which is not easily diagnosed on the pediatrician's usual screening test, as these exams look primarily for near-sightedness. My kids sailed through the screenings, despite the fact that we later learned that our son, James, had a different focal length in each eye. The potential vision problem only came to our attention through observations from his kindergarten teacher. She had noticed that James took a long time to answer some questions on the board and to do some assignments at his seat – he seemed painfully slow. When we had his eyes examined, we were shocked to find out he needed glasses, and that this was totally missed on routine check-ups. After getting glasses, James's speed on tasks jumped dramatically, and he went from being the last one done in the classroom to often the first. Subsequently, we had our second son's eyes examined prior to entering kindergarten, and were equally shocked to find that he was seeing +5.00 in both eyes! While he could clearly read the smallest line on the chart at the doctor's office, print and pictures in books in front of him were just blurs. We joked he could read the date on a coin at 50 yards, but could not see his own fingers clearly, and there were very few, if any, clues that his vision needed correcting. Glasses easily corrected both boys' vision, and I have become a huge advocate of pre-school comprehensive vision testing as a result.

## **Hearing**

Unlike vision, hearing can be affected in a more broad-spectrum way. While we seem to have more time to identify vision problems and correct them, hearing for good speech and language development is vital. Around age 2, children are beginning to speak clearly and learn to communicate, so good hearing is vital. A hearing deficit will impair a child from learning how to repeat sounds accurately, as well as coordinate all the muscles required to produce those sounds.

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<sup>28</sup> American Academy of Ophthalmology,  
[http://www.medem.com/MedLB/article\\_detailb.cfm?article\\_ID=ZZZOO3DZF4C&sub\\_cat=117](http://www.medem.com/MedLB/article_detailb.cfm?article_ID=ZZZOO3DZF4C&sub_cat=117).

While we measure the ability to hear by trying to determine what range of sounds (high to low pitch) and what intensity (loud to soft) people can detect, even mild hearing loss as a youngster can effect a child's development of oral language and speech. Besides mere volume and pitch, the clarity or "focus" of sound is also important, to hear many of the more subtle cues from our environment. Kids must simultaneously develop the ability to attend to certain sounds, while filtering out other noise as background or unimportant.

According to the American Academy of Otolaryngology, there is a six year window from birth to age 6 for children to develop oral language, in which hearing accurately plays a critical part.<sup>29</sup> Ear infections, common in young children, are also cited by the Academy as the most common cause of hearing loss in children, which can, in turn, delay their speech and language development.

In the PBS Series, "The Secret Life of The Brain,"<sup>30</sup> researchers discuss their findings in ongoing research about how children acquire language. At birth, children are referred to as "Citizens of the world" and their brains can learn any language, but as early as age 11 months, children have already begun to have their brains "wired" for the main language of their family and country, and do not hear the same fine distinctions in speech sounds that they could perceive just several months earlier. Obviously, this fast pace of development and acquisition of language skills requires that the main sensory input device for hearing, our ears, be operating as well as possible.

In the English language, we have 44 phonemes, or sounds, that make up our oral language. In order to speak, we must coordinate not only the precise movements of our tongue, cheeks and facial muscles, but we must also control the rate air passes over our vocal chords, adjusting it for tone, volume, and intonation, all of which we use in addition to the actual words to understand and communicate meaning to others. Hearing the subtle, softer sounds in speech and being able to reproduce them effectively is critical. Think about how things like humor, sarcasm, sadness, and joy are communicated through variations in tone, even when the exact same words are spoken. These subtle variations in speech production can drastically impact meaning. If a child is unable to perceive these variations, the comprehension of *what* is said, along with the shades of meaning delivered by *how* is said, will be lost.

Consider what happens when the ability to accurately alter your vocal tones is impaired, even temporarily, when you have a cold, sore throat, or even lose your voice. Because mucous around the vocal chords prevents them from moving freely, we can sound hoarse and are unable to maintain our usual range of vocal inflections. When this happens at my house, my husband might think I am unhappy or not as enthusiastic as normal, when in fact I am just temporarily unable to deliver my full range of meaning just by altering my voice. Likewise, if a child cannot coordinate all the equipment

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<sup>29</sup>American Academy of [http://www.entnet.org/healthinfo/hearing/hearing\\_loss\\_intervention.cfm](http://www.entnet.org/healthinfo/hearing/hearing_loss_intervention.cfm)

<sup>30</sup> DVD and Video of the series, and the associated book and website are available at [www.pbs.org/wnet/brain](http://www.pbs.org/wnet/brain). Copyright 2001 Thirteen/WNET New York.

necessary to produce intelligible speech, their ability to effectively communicate will be impaired.

Concurrently, if a child cannot hear all the sounds of speech clearly, they will not be able to produce them clearly. The connections that need to be made between the brain and oral motor muscles and the ability to coordinate these muscles effectively rely in part on the feedback we get from our ears. Just think what happens if someone is talking to you and you have on headphones. Almost always, people initially speak loudly or yell at the other person, because the input from the headphones supplies the brain with the message “There is a lot of background noise, and I must speak loudly to be heard over it”, so our speech output is much louder than it would be if we could hear ourselves talking without background interference. Likewise, the regulation of volume to meet surrounding social cues, like not talking above a whisper in church or at the library, or trying to get someone’s attention but not let everyone know what you are trying to say, depends on being able to adjust the complex requirements of speech to the feedback we get from our ears and our cognitive centers.

While a good deal of experience is often required to learn the ins and outs of how any one person feels by listening to their speech patterns and inflections, people within a family often become very adept at this skill with each other. If a child has a hearing impairment, or cannot read these subtle cues about what is happening around him, he will miss the verbal tone warnings when, for example, Mom is becoming frustrated and upset – these just fly right on by. Then the child is shocked and upset when Mom “loses it” and gets angry, because the child did not get or perceive the vocal warning signs that trouble was clearly on the horizon.

In a domino effect, the inability to hear the subtle differences in speech can impact written language, when learning how to read, spell, and write depend on being able to hear the variations in sound and place them in specific order to form words and sentences. For example, we all sound different with a head cold, and speech sounds, received and expressed, are not as clear as they are normally. Spelling “I have a stuffy nose” for a beginner with a head cold might be spelled phonetically “I hab a stuvvy node” because the interaction between the ears and speech production centers, as well as the ability to translate that information into letters and words are all interdependent. Spelling accurately depends in part by being able to sound out words yourself, and then process what letters go together to make these sounds. If you cannot hear these individual sounds, or if you cannot accurately reproduce the sounds yourself, it becomes much more difficult to master the whole concept of phonics while learning to read and write.

If hearing impairment is not detected early, the child may have to undergo intensive speech therapy to be able to correct annunciation and learn to pronounce the sounds well, so they can be understood by others, and accurately express themselves. Likewise, language therapy may be required to help things like grammar, intonation, and vocalization. Children with language disorders can have problems when learning to express themselves orally or in writing, because often the “gears” in the mind can work faster than the communication apparatus, and thoughts can come out in a big, mis-

ordered, jumble, missing key information that will help them be understood by others. Sentences may be overly simple and concrete, and not contain all the information we need to understand what has prompted this rush of information. While study skills and language therapy can improve these skills over time, it can be incredibly frustrating for the child to be repeating themselves, told to always slow down, and feeling unable to communicate all their thought and emotions even to those they love most, let alone the frustration they will suffer at school. If a child loses part of their hearing, hearing aids can be used to make things louder for the child, and easier to hear, but background noise will likewise be amplified, but the clarity of the sound itself may not improve. The lack of clarity will make it more difficult to learn to produce speech accurately, and to making discriminations between certain key phonemic sounds, impacting the acquisition of reading and writing skills.

The surprisingly subtle nature of hearing and its feedback to our brains that allows us to produce speech and language so naturally will, in turn, affect a child's ability to perceive language and express themselves with language. While not definitively proven, expressive and receptive language disorders seem to be logically impacted and even driven by the ability or inability to listen and reproduce sounds. Central Auditory Processing disorder, a learning disability that affects the ability to comprehend or make sense of what is heard, is very difficult for children, because it delays their reactions to auditory information and instructions, even when the "data" is being communicated perfectly to the brain by the ears. Both of these learning disabilities may at least be partially attributed to whether the sense of hearing or its perceptive framework within the auditory centers of the brain is working as it should.

### **The Other Senses: Smell, Taste and Touch**

Smell, taste and touch sometimes get left behind as "less important" than vision and hearing, as key aspects of input to the brain about our environment. However, they have key roles in giving our brains information about our bodies and what actions should be taken in response to these stimuli, and they are powerfully tied to the emotion centers in the brain.

Taste and smell are some of our more "primitive" functions, located closer to our brain stems in a part of the brain called the amigdala. This area of the brain is also responsible for our "flight or fight" response, mood, and other emotional reactions, helping to form powerful autonomic responses, that also help us encode things in our memory unlike vision and hearing. These senses are almost always closely associated with emotions, as the smell of a pumpkin pie can take you back to your grandma's kitchen when you were only four; the smell after a fresh rain in the spring can remind you of days at summer camp; or the taste of fresh lemonade reminds you of the time you and a friend drank all the lemonade from your first attempt at the sales business at the base of your driveway as a kid. Some people, such as professional actors, become very adept at summoning these sensations and their related emotional responses on cue, so that in the moment, their tears are not faked, but real, and they are actually experiencing the

emotions they are portraying on stage, including all of the physiological changes necessary to produce and relive that moment, time and again. This is perhaps the ultimate ability to “get in touch with your emotions”.

Touch is also somewhat complex. Nerve endings all over our body can sense temperature, texture, and pain, and give us vital information about our bodies location in space. Through the early experiments with primates cited above, we know how important loving touch can be for the proper emotional development of children. Children who are not held can fail to thrive, and even die. Even as adults, touch is an important indicator of an emotional bond, both within families and in the outside world. Lyndon Johnson, for example, was well known for using a pat on the back and his handshake to help persuade the political opposition. Patient’s opinion of their physician is formed by the kind of touch they receive during an exam. Research has also shown that a gentle hand on the back or arm of a customer by a waiter or waitress can increase the tips left at the end of a meal. Adults who grew up in non-touchy homes can be heard to lament that they never received hugs from their parents. And of course, refusing to shake hands during or after a sporting event is considered the ultimate dismissal of the importance of another person. Touch is very clearly a subtle message of acceptance and approval that runs through our culture.

With the strong emotional link smell, taste and touch have to the well being of children and adults alike, what happens if that system is not working properly?

### **Sensory Overload**

We can all become sensitized to “sensory overload”. It seems as if we all have a certain amount of stimulation we can take before we need to reset our circuits and prepare to receive more information from any of our senses. For example, most conferences for adults will have a schedule allowing for a coffee break mid-morning, lunch about an hour and a half or so later, a mid-afternoon break, and then close, all at about ninety minute intervals. Why is this? It turns out that for optimal learning and acquiring information, the brain needs time to consolidate information and “pack it” for future use. If too much information or stimulus is received, a lot of it will simply not be transferred into long term memory.

Likewise, too much environmental stimulus will begin to make people irritable and angry, or even cause them to shut down completely and sleep. Without a break, or a way to reset our stimulus thresholds, we will begin to react emotionally. For example, infants can often sleep in very noisy environments- their brains simply require them to totally shut down and avoid stimulation they can no longer handle. Kids get irritable at the end of the day, mostly because they have had all the stimulation they can take, and they simply need to rest and regroup. Moms will often try to multi-task in the evenings, making dinner and lunches, talking on the phone, and managing kid homework at the same time. In our house, there comes a threshold at which any additional interruption from my children sends me over the edge, and I become angry or irritated at their question than I normally would be. This over-reaction is due to the fact that I can no

longer adequately process all the stimuli I am receiving, and I snap, because that little interference with my ability to process information sends the whole task-balancing act to the ground. It isn't the child's fault, it is mine, and simply due to over-stimulation. Likewise, we have all had hard days at the job or at home, where at the end of the day, you are simply emotionally and physically exhausted, even if you did not do that much physical work. Our ability to handle all the information our brains have received during the day has been used up, and we just want to rest and sleep, in order to be able to reset our "stimulus clocks" to prepare for another onslaught the next day.

Most of the moms I know make sure they have ample amounts of snacks in the back of the minivan at any given time, because this opportunity to nutritionally recharge prevents a lot of emotional tumult from the kids, and from this unrest making her life equally unpleasant. We provide play time or breaks in the middle of homework, to allow our kids to be able to go to the next task refreshed and better able to concentrate and focus. In fact, the whole purpose of "time-outs" in discipline is to take a child out of a situation where they are receiving positive feedback for negative actions, and remove this "reward". We are, in essence, recognizing our kids have reached sensory overload, are reacting to it strongly, and we try to reset their stimulation clock to zero. These are basic things we all do when raising kids, but they work because they allow the brain breaks to consolidate information and get ready to receive new input effectively again, much like saving a document on your hard drive, which makes it usable again later.

## **Sensory Problems**

For most people, our sensory systems have a sense of fatigue. For example, when we walk into a kitchen where cookies are baking, we are able to smell them right away, but after a period of time, the intensity of the odor diminishes. Likewise, when we put on clothes in the morning, we are more aware of the fabrics and how they feel, but our nervous system rapidly learns to ignore every single motion of the fabric against our skin all day long. A first bite of a favorite food is divine, but by the end of a full meal, it is no longer the same sensuous experience it was at first taste. What would happen if our sensory systems did not have this sense of "desensitization" or fatigue? Firstly, our nervous systems would be much more aware on an ongoing basis of all incoming stimuli, and this cascade of neuronal information would simply overload our brains, distracting us from other tasks and inhibiting our abilities to concentrate and function. To various degrees, there are individuals and children who have this sensory dysfunction, although there is ongoing debate about what it is called, and what treatments might be effective.

So what happens when a child has a problem with their sensory apparatus? In some children, the input sensory systems may all be working properly, but for some reason, the perception of the stimulus seems magnified. These children seem abnormally tense – sounds seem to always be too loud for them, smells make them crazy, tags in the back of clothing are distracting and uncomfortable, they tend to eat an abnormally restricted number of foods and be sensitive to textures, and even can be sensitive to light. There is quite a bit of controversy about whether such children have Sensory Integration Disorder, first described in the 1970's, or fit somewhere along the Autism Spectrum

Disorders, which include classic autism, high functioning autism, childhood disintegrative disorder, Rett syndrome, pervasive developmental delay, and Asperger's Syndrome. Significant research is being done to better understand the causes of these disorders, which can have devastating effects on children and their families.

Sensory Integration dysfunction was first described by Dr. Jean Ayers, a physical therapist, as an inability for a child to integrate the sensory information they were receiving and have it make sense, especially as it applied to motor planning. This means a child with sensory integration issues, for example, did not seem to be getting accurate feedback from their fingers about their position in space, and may be unable to coordinate visual information about letter shape in such a way to then be able to coordinate those fine motor distal muscles in such a way to be able to manipulate writing implements well, making handwriting very difficult. Children can have large motor issues, including walking, running skipping, climbing- all of which involve advanced motor planning- often referred to as coordination, or fine motor issues, usually showing up as problems in lacing shoes, doing buttons, writing, and manipulating small objects. These problems can cause kids to be clumsier than their peers, have difficulty participating in sports and gross motor activities that are otherwise age-appropriate, have terrible handwriting, and even avoid doing things like lace their shoes. Kids may have balance problems making bike riding difficult. These motor issues, often accompanied by extreme sensitivity to sensory input from vision, hearing, taste, smell and/or touch led Dr. Ayers to suspect the neural coordination of sensory information had gone awry, and recommended all sorts of physical therapy treatment to try to improve coordination and motor planning as well as desensitize children to stimuli so they could better function in their environment.

Since many children with extreme sensory issues have many features in common with children diagnosed with Pervasive Developmental Delay and Asperger's Syndrome, some people are beginning to believe sensory integration issues belong somewhere on the autism spectrum. In fact, most of the issues described by Dr. Ayers as symptoms of sensory integration dysfunction, are becoming emerging issues of children along the autism spectrum, particularly the interplay between sensory sensitivity and fine and gross motor delay, and sensory integration therapies are being used extensively to help children with many of the five acknowledged autism spectrum disorders.<sup>31</sup>

One of the symptoms in common with many of the autism spectrum disorders is a hypersensitivity to touch. Many autistic children do not like being touched, have significant issues with clothing, especially tags in their shirts and pants. They may be extremely sensitive to sound. They seem to have a heightened sensitivity to smells and tastes, leading them to have very picky eating habits, often based on textures. Some of the best information we have on what it is like to be autistic comes from Dr. Temple Grandin, an autistic adult who has been outspoken about her autism.<sup>32</sup> Dr. Temple describes wanting the comfort of touch, but that the touch itself was so over-stimulating for her nervous system, it was overwhelming. Touch became something to be avoided for its lightening-type effect, rather than fear or anger at the person doing the touching.

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<sup>31</sup> <http://www.coping.org/copingbook/autism.htm>

<sup>32</sup> <http://www.autism.org/temple/visual.html>



Tactile therapy to desensitize the nervous system in both sensory integration disorder children and those with autism spectrum disorders may be helpful, even increasing eye contact and improving speech.<sup>33</sup>

Since touch is one of the many things we use as part of our social bonding, many children with autism spectrum disorders and sensory integration problems have secondary social skill problems. Besides often being “non-cuddly” children at home with their families, these kids are no less touch-adverse with their peers. People touching them or bumping into them may cause them to over-react. Affected kids are often worried about noises that are too loud, making gym class, or going bowling with friends difficult, if not impossible. Going to arcades, indoor climbing gyms and the like may also be way too loud for these children, meaning their interaction with their peers can be diminished. Their overall sensitivity to stimulus may make them very cautious about any new situation, and they may become very risk-averse. Many parents need to discuss and plan trips in advance, to prepare their kids for possibilities, so they are not surprised and over-whelmed by the unexpected. As a result of avoiding sensory-overload experiences, these kids often miss out on many group activities, and tend to lag well behind their peers in identifying the emotions of others, also being less likely to be able to accurately predict how others kids will react. Lack of social experience along with the constant bombardment of sensory stimuli make these kids even less likely to have spent significant time observing and studying how people act, watching body language, tone differences, looks, and the more subtle aspects of human behavior which allow us to interact well with others.

Imagine what it must be like to be a child with sensory problems. Not knowing many of the silent social cues we get about whether we “fit in”, or the appropriateness of our behavior and dress for the surroundings, also means not knowing how to correct for social awkwardness. The chances that the child will be picked on by their peers, not picked for teams, or otherwise have difficulty making friends goes up exponentially. These children often want friends, but they have few skills that let them make and keep close friends. They often end up feeling excluded and become even more resistant to trying new social situations, creating a negative feedback loop that is hard to break. This can be the most difficult disability for kids, as school and most employment opportunities later in life depend on being able to interact with others in social settings as well as the purely academic.

It is important to note while there are many speculations about the cause of autism and its related disorders, there has not been any definitive evidence laying blame on any one environmental, medical or developmental issue. It seems clear however, that the sensory pathways in the brain of these children are somehow oversensitive, and their perception of sensory information is much more intense than in most children.

## **Parental Pointers**

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<sup>33</sup> Id.

- Accurate sensory input from all the senses is necessary for optimal brain development.
- Parents should be particularly careful to make sure their children can see well; this may mean a visit to an eye care specialist, as the screening tests given in pediatric offices and schools may overlook some vision problems.
- Parents should make sure their children hear well. This means not only hearing the loudness and softness of sound, but also hearing clearly. Ear infections can leave fluid in the eustacean tubes and ear canal, diminishing the acuity of the sound heard, having a potential affect on speech and language development.
- Speech and language development is complex, and has a direct bearing on the eventual acquisition and development of reading and writing skills.
- If there seems to be any delay in speech or language development, early intervention is key. The sooner a child's problems are diagnosed and addressed, the less adverse effect they will have on his long term development.
- If a child seems particularly sensitive to noise, light, touch, or smells, this may be a sign of a more serious problem, and should be watched carefully.
- While classic autism may include children who are very low functioning, there are many categories on the autism spectrum which include high functioning children, many of whom are extremely bright and may do very well as adults. They may have sensory issues and social skills may not come to them naturally, and they may need to be taught these skills in a more specific way.