EXPERT ANSWERS

Dr. Gordon Sherman on Brain Research and Reading

SchwabLearning.org

A Parent's Guide to Helping Kids with Learning Difficulties

Dr. Gordon Sherman on Brain Research and Reading

Articles

Resources & References

Gordon F. Sherman, Ph.D., is Executive Director of The Newgrange School and Educational Outreach Center in New Jersey. He was previously Director of the Dyslexia Research Laboratory at Beth Israel Deaconess Medical Center in Boston and Assistant Professor of Neurology at Harvard Medical School and is a former president of the International Dyslexia Association.

SchwabLearning.org®
A Parent's Guide to Helping Kids with Learning Difficulties

The Expert Answers: Dr. Gordon Sherman

Are There Structural Brain Differences in Kids with LD?

SchwabLearning.org asks:

Research in neuroscience has produced clear evidence of structural differences in the brains of children with reading difficulties. Can you tell us about these findings?

Gordon F. Sherman, Ph.D., responds:

Nature loves diversity. No two human brains are alike — by design. Diversity propels evolution by enhancing a species' ability to adapt to changing environments. How does this relate to dyslexia? Hold that thought while we talk about the brains of children with reading difficulties.

Brain Research

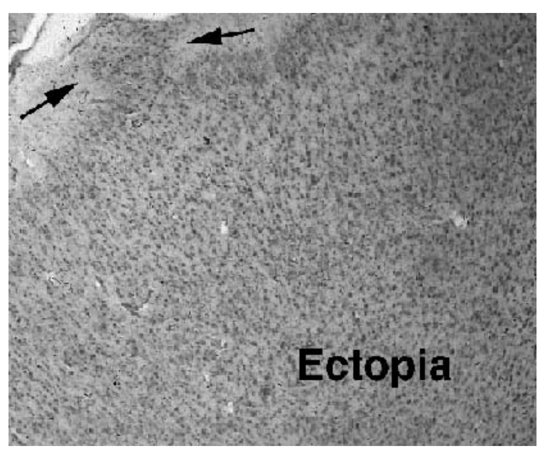
While no two brains are alike, the brains of people with dyslexia are distinctly different compared to those without dyslexia. Dyslexic brains function differently because they are organized differently. They even look different, though not to the naked eye. Scientists use microscopes and sophisticated neuroimaging tools to study the structural and functional differences of dyslexic brains.

Studies of brains donated to medical research advanced our understanding of developmental dyslexia in important ways. Scientists discovered structural differences in two parts of the dyslexic brain — the cerebral cortex and the thalamus. The cerebral cortex is the six-layered outer part of the brain involved in high-level processing, including sensory and motor analyses, working memory, attention, and language. The thalamus, a "way-station" located at the center of the brain, is the major stop for information transmitted from our sensory organs (e.g., eyes and ears) to the higher-level processing cerebral cortex.

Microscopic examination of autopsied brains revealed changes in the arrangement of nerve cells and a smaller auditory region — both in the cerebral cortex. Measurement of nerve cells in visual and auditory parts of the thalamus revealed smaller cells. These studies provided the first evidence of a brain-based cause for developmental dyslexia.

Differences in the Cerebral Cortex

Let's look more closely at the changes in the cortex. One concerns **ectopias** . These are small bunches of nerve cells (neurons) and bundles of tangled nerve fibers (axons). Imagine a microscopic jellyfish with tangled tentacles, and you have some idea of what ectopias look like. Their other distinctive characteristic is their location — within the first layer of the cortical areas responsible for language. Nerve cells normally are absent in this top layer.



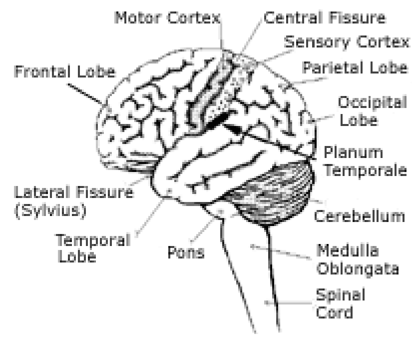
These ectopias are caused by a change during neuronal migration — the journey all newborn neurons undergo to their final positions in the brain. But some newborn cells miss their stops, travel too far, and end up in foreign locations in the cortex, becoming altered in the process and connecting to the rest of the brain in atypical ways.

Are There Structural Brain Differences in Kids with LD?

Scientists believe that ectopias occur in the developing brain of the fetus before its sixth month, since most neurons find their adult positions by that time. Because ectopias occur early in development and because dyslexia often runs in families, scientists suspect that genetic differences affecting early brain development cause ectopias.

The fascinating thing about ectopic neurons is that they seem to connect with neurons in other parts of the brain differently. Since most ectopias are in the language networks and the frontal part of the brain related to verbal memory, it is easy to see how a different "wiring" pattern might affect the complex process of learning to read and write.

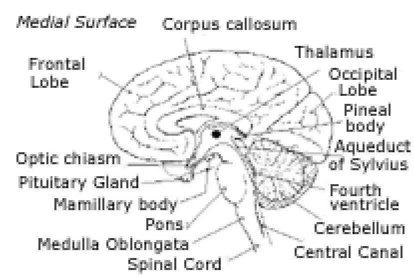
Another cortex difference — **symmetry** — has been found both in autopsied brains and in neuroimaging studies of living people with dyslexia. The human brain has two hemispheres that are almost, but not quite, mirror images. Not quite, because small size differences — asymmetries — exist between hemispheres. (The two hemispheres also process information, including language, somewhat differently.) Studies show that the planum temporale, an auditory region that is part of the language network, is the same size in both sides of dyslexic brains. In other words, dyslexic brains are more symmetrical.



Why is this news? Because the planum temporale normally is larger on the left side of the brain. This asymmetric brain design may be highly efficient for processing sequential information and for learning certain language skills, including reading, writing, and spelling. Symmetry of this area may interfere with learning to read and write.

Differences in the Thalamus

Scientists discovered yet another difference in autopsied dyslexic brains — smaller neurons in certain cell clusters (nuclei) of the thalamus. The two affected nuclei are dedicated to vision and hearing. Although scientists do not know exactly how size relates to function, smaller neurons in these two areas may disrupt the exact timing required to efficiently transmit information across brain networks.



The Challenge for Researchers

Scientists do not suggest that every struggling reader has these structural brain differences. However, these studies provide evidence that some children's learning problems are brain based — though independent of intelligence levels. The challenge for scientists is to determine exactly how these structural differences affect children's ability to learn to read.

Diversity and Evolution

Now, let's return to that thought we were holding — how do diversity and evolution relate to dyslexia? While a dyslexic brain may not be ideally suited for processing certain sequential and linguistic information, perhaps its symmetry and connection differences constitute an ideal design for other kinds of processing. Indeed, teachers of children and adults with dyslexia often remark that many have unusual strengths.

In other words, children with dyslexia have strengths and weaknesses like all children. However, a disproportionate number may have exceptional strengths that can enrich all our lives. And, given the fact that environments always change, who knows what diverse minds our species will need in the future?

The Expert Answers: Dr. Gordon Sherman

What is the Environment's Effect on Reading Problems?

SchwabLearning.org asks:

We understand people with dyslexia have differences in brain structure. How can educators use this knowledge to teach more effectively, thus preventing or diminishing reading disabilities?

Gordon F. Sherman, Ph.D., responds:

Brains of people with dyslexia are different in many ways. Starting early in life, the language network and certain sensory systems develop along a unique trajectory. It is the interaction between genes and environment that modifies the development of these systems, producing a distinctive learning profile we call dyslexia. Dyslexia varies from individual to individual in the combination and degree of strengths and weaknesses, due to the intricacies of brain development and countless environmental variables. Dyslexia is lifelong but amenable to educational intervention.

How does this neuroscientific view of dyslexia inform teaching of children and adults with this learning disability? Let's explore the interaction of these brain-based differences with the environment.

> "The educational environment … can offset neural processing weaknesses and encourage latent strengths to blossom into competencies and talents."

Modified Language/Sensory Systems

In dyslexia, the cortical language network of the brain is a network distinctly different in appearance, organization, and function. These differences probably account for the fact that most people with dyslexia need direct instruction in phonological processing (producing/interpreting language sound patterns) and in alphabetic skills (written symbols representing speech). Weak phonological and alphabetic skills set the stage for a complex set of consequences, including difficulty learning to read, write, and spell.

Another difference involves the sensory nuclei of the thalamus. There are smaller nerve cells in lower-level visual and auditory processing centers that may affect processing of fast information — like flashing pictures or rapidly presented words or sounds. (Some findings link a deficit in fast processing with severe language difficulties, although this hypothesis is controversial.)

Clearly, brains with atypical language and sensory systems are at a disadvantage in a traditional educational environment, where fast-paced, linguistically loaded instruction prevails.

Other Brain-based Conditions Complicate Dyslexia

Another brain-based condition, Attention-Deficit/Hyperactivity Disorder (AD/HD), may exacerbate dyslexia. Motor, attention, and arousal systems differ in many people with dyslexia. Add increased impulsiveness, distractibility, and hyperactivity to modified language and sensory systems and big challenges can ensue, particularly in learning to read. Lack of precise regulation of neurochemicals in the brain (i.e., fluctuating amounts of dopamine) may cause AD/HD.

What is the Environment's Effect on Reading Problems?

Environment Plays a Role

Achieving success with dyslexia, especially when combined with AD/HD, can be a circuitous and uphill struggle. Nevertheless, people with this learning disability often excel, achieving routine and singular accomplishments in life. Almost always, though, their stories involve painful struggles with the educational system — where most dyslexic brains function as square pegs in round holes. Not because they are inferior, as the achievements of people with dyslexia attest, but because the peg and hole do not always match.

The point here is subtle but important — **the environment can render the learning difference a learning disability**. Far from an esoteric or semantic distinction, this scientific perspective informs enlightened educational planning and policy, illuminating solutions and reasons for implementing them. Dyslexia is an example of human brain variation. Human diversity is more than a politically correct concept. Diversity propels evolution by permitting adaptability to various environments. History and science tell us that environments inevitably change and that brain diversity may benefit our species.

> **"Dyslexia varies from individual to individual in the combination and degree of strengths and weaknesses, due to the intricacies of brain development and countless environmental variables."**

This is **not** to say, however, that dyslexia is a minor learning problem or some inconsequential blip falling within the normal range of variation. Parents and educators alike must recognize that dyslexia is a distinctly different brain organization that can be profoundly disabling, particularly in the context of a poorly designed educational environment.

Educational Environments

So, how do we modify the educational setting to prevent a distinct difference from becoming a profound disability? How do we design educational environments to reduce struggles, capitalize on strengths, and maximize success for people with dyslexia — enabling them to contribute their abilities and talents?

You might be surprised to learn we already have answers to these questions, and the answers benefit **all** learners.

While there is no cure for dyslexia (efforts to cure it may be misguided anyway), effective approaches for teaching reading and writing skills to children with dyslexia **do** exist. These research-based approaches incorporate several critical components. They deliver a structured-language curriculum in a sequential, systematic, and cumulative way — offsetting language, sensory, memory, and motor/attention processing differences. More specifically, these approaches provide explicit instruction in phoneme awareness, phonics, reading fluency, vocabulary, and reading comprehension skills. All of these are fundamental to becoming a proficient reader.

Indeed, reading research tells us effective early literacy instruction for **all** children includes these elements. All children benefit from well-informed instruction in phonics, comprehension strategies, language development, and writing skills, as well as from exposure to rich fiction and nonfiction literature.

This is not to say an eclectic mix of code-based and meaning-based teaching equals effective reading instruction. Unfortunately, in classrooms across the country, "balanced reading instruction" has been interpreted as a dash of this and a dollop of that, or as equal focus on phonics and whole

What is the Environment's Effect on Reading Problems?

language. Since many teachers have more experience with whole language and less expertise in structured language, the resulting hybrid usually skews toward whole language (which minimizes structured-language teaching in order to preserve focus on meaning). More often than not, the eclectic mix does not meet the standard of the research-based, systematic, structured-language teaching recommended for all students, particularly for beginning readers.

All brains can suffer disabling consequences from poor instruction. However, those that depend most on effective teaching are penalized most severely. Students with learning difficulties and others at risk for failure or underachievement pay the highest price for poor teaching. Effective instruction in general education classrooms in early grades is vital for children with dyslexia because most do not receive special education services until after second grade, **after** they have failed to learn to read. The good news is we can prevent this failure for many.

Clearly, circulating the scientific evidence about what constitutes good instruction is not enough to guarantee children will receive it. The need to understand the dynamics of school change is becoming obvious as educators and policy makers attempt to implement research-based knowledge about effective instructional practices. So, too, is the critical need to impart the essential competencies to teachers through preservice and inservice teacher preparation programs. Teacher attitudes and knowledge, including how the English language is constructed, are fundamental to implementing effective instruction.

Summing Up

To recap, processing differences in multiple brain systems cause fundamental difficulties in acquiring phonological and alphabetic skills. Weaknesses in these skills set the stage for academic problems in areas such as decoding, fluency, comprehension, written expression, and spelling. These problems, in turn, can lead to various negative educational and social consequences.

Fortunately, while dyslexia is brain-based and lifelong, we can prevent and diminish reading disabilities and forestall associated academic problems. The educational environment plays a key role. It can translate a distinct way of learning differently into a profound learning disability. Or it can offset neural processing weaknesses and encourage latent strengths to blossom into competencies and talents. A structured-language curriculum delivered through explicit, sequential, systematic, and cumulative instruction by highly skilled teachers is a critical component in an optimal learning environment, particularly in the early grades.

Happily, designing educational environments to enhance learning for children with dyslexia benefits all learners. However, changing these environments in order to initiate, nurture, and sustain effective teaching is challenging. Implementing effective instruction depends on teacher competencies and requires understanding of the complex dynamics of school change.

In coming weeks, we will discuss multisensory instruction, early intervention, and the ways the environment actually alters brain function. In the meantime, try thinking about dyslexia from a neuroscientific perspective. Dyslexia is neurologically based. It can be disabling, particularly in the context of a poorly designed and heavily text-oriented educational setting. The environment determines the extent of the disabling consequences. Changing the environment can prevent or diminish a disability.

The Expert Answers: Dr. Gordon Sherman

Can Neuroscience Help to Demystify Dyslexia?

SchwabLearning.org asks:

How will neuroscientific tools like neuroimaging help us understand dyslexia, fine-tune its identification, and enhance educational intervention?

Gordon F. Sherman, Ph.D., responds:

Neuroscientific tools, such as neuroimaging, promise to play a key role in the unfolding story of dyslexia — helping to clarify misconceptions, dispel controversy, and improve diagnosis and intervention.

Dyslexia results from a complex gene-environment interaction that begins in the womb and eventually modifies both the structure and function of the nervous system. This prompts the brain to develop according to a different blueprint. The result is a brain that does not process language in the usual way. Even with all we understand about this atypical development, mysteries remain.

> “The brave new world of neuroimaging promises to put many dyslexia debates to rest … neuroimaging allows us to probe the frontiers of the human brain.”

Controversy and Confusion

Why do controversy and confusion often surround dyslexia? Partly because the work of the researchers, educators, and evaluators concerned with dyslexia often rests on inference — inferred assumptions about normal and atypical brain development and function.

Historically, to investigate the structure and neurophysiological function of brains, neuroscientists have relied on the examination of brains obtained at autopsy or on studies of patients during neurosurgery. To understand learning and learning disabilities, clinicians and educators rely on closely observed behavior patterns. Scientists, clinicians, and educators study neural tissue or behaviors to infer what the brains of their patients, subjects, or students actually do in normal living and learning conditions.

Given the inexact nature of inference, many conclusions about dyslexia are subject to interpretation, and, thus, plagued by controversy. Since Pringle Morgan and James Hinshelwood first described dyslexia a little over 100 years ago, scientists, educators, and clinicians have debated dyslexia's definition, diagnosis, treatment, and even its existence.

Now, however, the brave new world of neuroimaging promises to put many dyslexia debates to rest. Much like the Hubble telescope enables us to see into remote corners of space, neuroimaging allows us to probe the frontiers of the human brain. As neuroimaging technology progresses, we will “see” the structure and functioning of living brains with increasing clarity — a scientific advancement beyond anything Morgan or Hinshelwood could have imagined.

Modern neuroimaging techniques, showing the activity of brain areas and networks, will help unravel the mysteries of dyslexia. While traditional neurological studies and clinical observations continue to provide valuable information, neuroimaging offers a window for viewing the structural and functional attributes of living and learning brains. Thus, neuroimaging promises to enhance the diagnosis of dyslexia, the design of educational programs, and the precision of prescriptive teaching.

Can Neuroscience Help to Demystify Dyslexia?

Neuroimaging May Aid Diagnosis

Here is the most widely accepted definition of dyslexia:

> Dyslexia is a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge.
> *Adopted by the International Dyslexia Association Board, November 2002, and by the National Institutes of Health, 2002*.

Although this definition has proven useful, particularly for research purposes, it does not give us a concrete understanding of dyslexia.

- Exactly what is different about the brain of a person with dyslexia? What are the brain-based mechanisms for the types and degrees of dyslexia?
- How do we diagnose dyslexia?
- How does the environment alter brain structure and function in dyslexia?
- What are the best methods of instruction for people with this learning disability?

Neuroimaging may lead us to a more precise definition of dyslexia, providing more specific information about its neurological basis and characteristics which, in turn, may yield additional diagnostic and educational insights.

Advanced neuroimaging tools also may aid in the diagnosis of dyslexia. Techniques such as PET (Positron Emission Tomography) and fMRI (Functional Magnetic Resonance Imaging) reveal the activity of the brain during tasks such as speaking, reading, and writing. If people with dyslexia show consistent and characteristic differences in brain function during such tasks, demonstrating a distinct "neurological profile," this information may lead to more precise identification and educational intervention.

Certainly, today's neuroimaging tools are too cumbersome and expensive, even too rudimentary, to be useful for common screening and diagnostic purposes. But who knows? Consider our remarkable evolution since Morgan and Hinshelwood. Technological advances making neuroimaging part of every child's kindergarten screening may be less science fiction than we might imagine.

Evaluating Educational Interventions

Neuroimaging also may help us discern the precise instructional elements that work best for teaching students with dyslexia how to read, write, and spell.

For example, some propose that supplementary non-language treatments directed at the visual and auditory systems benefit the struggling reader. This, however, remains controversial. It has been difficult to establish the efficacy of these approaches. Imaging the brain before and after using these techniques may provide the clues necessary to determine if they do benefit learning.

Can Neuroscience Help to Demystify Dyslexia?

While science has verified structured-language instruction, researchers have yet to study the "multisensory" component educational therapists and teachers often include, particularly for students with dyslexia. Multisensory instruction conveys information through multiple input channels (visual, auditory, and kinesthetic/tactile) and enlists various multisensory strategies to enhance memory storage and retrieval. Multiple sensory channels feed comprehensive and concrete information to the language-processing network of the brain. Theoretically, multisensory instruction bypasses sensory-system weaknesses, conveys information to an atypical language system in more decipherable and indelible forms, and provides various "triggers" for memory.

In multisensory instruction, a student might be instructed to **look** at a letter (visual), **listen** to its sound (auditory), **associate** the letter and its sound with a picture of a "key word" that "unlocks" its sound (e.g., apple/short a — visual/auditory), **say** the letter with its sound (kinesthetic/auditory) and perhaps its key word, and **write** the word and perhaps **move** or **gesture** in some way that represents the key word, letter, or sound (kinesthetic). A variety of structured-language/multisensory programs employ versions of such methods, usually in inventive and systematic ways. Their goal is to achieve multiple pathways and associations for input, storage, and retrieval to offset weaknesses in sensory, language, and memory systems.

> "Neuroimaging techniques reveal … how the brains of people with dyslexia change while engaged in basic language tasks after receiving structured-language educational interventions."

Clinical experience with this technique points to a powerful effect. From what we know about the brain and dyslexia, multisensory instruction would seem to be an important component in teaching students with this learning condition, perhaps even beneficial for all students. But science has not yet addressed the efficacy of multisensory instruction. "Seeing" the brain at work through neuroimaging may help establish the merits of this instruction and enable educators to refine its elements. Neuroimaging may help us understand the apparent magic of multisensory instruction.

What We Have Learned

Neuroimaging techniques reveal a brain far more complex than previously thought. For example, the language network appears to involve more than a few "key centers" and may be distributed in other brain regions, contrary to earlier hypotheses. We have also learned how the brains of people with dyslexia change while engaged in basic language tasks after receiving structured-language educational interventions. In general, these changes entail shifting to a more efficient, unilateral mode of processing. In the coming week, we will discuss these remarkable findings in greater detail.

On the Threshold

Will advancements in neuroimaging dispel all the controversies and confusions surrounding dyslexia? Probably not. They will, however, bring us breathtakingly closer to understanding the mysteries of the brain. Along the way, these advancements will help us demystify dyslexia, sharpen its definition, fine-tune its diagnosis, and verify the efficacy of educational interventions. Indeed, we are on the threshold of a brave new world — one where neuroscience and education will combine to unlock and enhance human potential in powerful new ways. Morgan and Hinshelwood would have been astonished! We, however, need only a little vision to find and cross the threshold.

SchwabLearning.org®
A Parent's Guide to Helping Kids with Learning Difficulties

The Expert Answers: Dr. Gordon Sherman

What is Neuroimaging's Potential Impact on Education?

SchwabLearning.org asks:

What if you could see inside the brains of people with dyslexia and watch them think? Compared to brains of people who don't have dyslexia, would you see fundamental differences? Is this a scenario from the pages of a sci-fi thriller?

Gordon F. Sherman, Ph.D., responds:

The answers to these questions are, respectively: you can, you would, and no! Modern neuroimaging **has** made it possible to "see" inside living, performing human brains. Using high-tech imaging tools, scientists have discovered that dyslexic brains **do** function in atypical ways consistent with the structural differences discovered nearly two decades ago. Finally, these are findings from the pages of scientific journals, **not** from science-fiction literature.

> "… as struggling readers begin acquiring literacy skills, their brains do exhibit "activation patterns" similar to those of non-impaired readers. Think of these changes like a computer."

Neuroimaging provides a computer-analyzed view of how the brain looks and functions, showing which areas "are activated" (i.e., working hard) and which are not. We can watch the brain while it performs complex cognitive activities and while it is at rest, though it never really rests.
While technological advances promise ever sharper images, today's neuroimaging techniques and computers already provide an arresting view of the brains of people with dyslexia. There are new findings on subtle structural differences, but the most intriguing findings concern functional attributes — **how** these brains work differently.

Dyslexia: Distinct Patterns of Brain Activity

Studies from around the world show a distinctly different pattern of brain activity in subjects with dyslexia as compared to people without dyslexia.

Neuroimaging studies from the United States, Japan, Germany, Italy, and other countries compared impaired (dyslexic) readers to unimpaired (control) readers ranging in age from 8 to 54. A variety of imaging techniques (fMRI, PET, MEG, MSI) monitored subjects' brain activity. The most commonly used technique, fMRI, is safe and noninvasive and uses radio waves and magnetic fields to show blood flow in areas of the right and left hemispheres. Areas with increased blood flow are hard at work and show increased "activation."

In these studies, subjects performed phonological processing tasks (e.g., silent reading, rhyming, or pronouncing words and nonsense words). A number of consistent findings emerged. The first is that during these language-based tasks, key areas of the language network in the **left** temporal, parietal, and occipital lobe "**under**-activated" in people with dyslexia, while left frontal areas "**over**-activated." The second finding is that, in subjects with dyslexia, certain **right**-hemisphere areas "**over**-activated."

What do these findings mean? In most people, left-hemisphere areas specialize in language and "activate" on language tasks, reflecting a specialized brain design that, in general, promotes efficiency.

What is Neuroimaging's Potential Impact on Education?

However, these new studies showed the brains of subjects with dyslexia function more bilaterally — in other words, they use areas in **both** hemispheres for language tasks, usually a less efficient mode for processing sequential information and certain language skills.

Bilateral and Neurocompensation

The increased activity in both the left-hemisphere **frontal** area and in areas of the right hemisphere may reflect compensatory mechanisms working to bypass deficiencies in left-hemisphere language areas. Neural compensation is a good strategy for circumventing specific structural and functional shortcomings, a phenomenon well-known in cerebral stroke patients who learn to accommodate to an injury by transferring function from damaged to intact regions. A similar but developmentally unique phenomenon appears to be at work in dyslexia, though the compensation mechanism may be imperfect, not entirely correcting the hallmark phonological difficulties often found in people with dyslexia.

Bilateral hemisphere activity also may relate to the structural symmetry in dyslexic brains. Areas in the right and left hemisphere of people with dyslexia are more symmetrical, more like mirror images, whereas these areas in most people are asymmetrical.

Educational Intervention May Change Brain Networks

A number of laboratories are working on documenting brain activity changes in people with dyslexia after educational intervention. Initial results are intriguing.

A substantial body of research demonstrates that structured-language programs effectively teach literacy skills to people with dyslexia, begging the question, do their brains change in response to this intervention and function more like unimpaired readers? Neuroimaging should reveal such a change, if it occurs.

Indeed, it appears that as struggling readers begin acquiring literacy skills, their brains do exhibit "activation patterns" similar to those of non-impaired readers. Does this mean the basic anatomical structure of the dyslexic brain changes? No. The fundamental structure does not change. But **functional** capacity may improve in two ways: 1) formation of new neural connections and 2) increased synaptic numbers and efficiency. Think of these changes like a computer upgrade — enhancing capacity to operate efficiently, to process complex sequential and linear information, and to improve memory storage and retrieval. For a child with dyslexia, these functional enhancements may mean the difference between success or failure in learning to read.

Implications of Brain Research

Already, we have learned the brains of subjects with dyslexia show characteristic and distinct functional differences compared to controls — less engagement of posterior left-hemisphere language areas and more bilateral processing. These findings are consistent with earlier findings from microscopic analysis of autopsied brains, showing structural variation in left hemisphere language areas and symmetry. We also have learned that environment can play a modifying role in dyslexia. The brains of subjects with dyslexia can change in response to structured-language educational intervention, functioning more like the brains of non-impaired readers. This last finding is compelling, but not surprising, and validates decades of clinical observations and reading research.

This finding also sheds light on implications that may transform education as we know it. Advancements in neuroimaging promise ever-sharper insights into the mysteries of the brain, allowing us to investigate more refined and targeted questions. Can neuroimaging studies become

What is Neuroimaging's Potential Impact on Education?

more precisely prescriptive, delineating which students do and do not show changes after specific interventions? Perhaps. What can we learn about the brains of people who have dyslexia in their family or who have certain genetic markers? What patterns will we see in the brains of people with excellent spatial skills, visual or auditory difficulties, or AD/HD? This is potent stuff. When we can answer critical questions like these, we may be able to prescribe educational interventions with scientific precision.

When might this prescriptive teaching vision become a reality? Don't plan on booking imaging appointments for Johnny or Jane in the near future. However, we are on the threshold of determining whether or not specific kinds of interventions work for specific kinds of learners. Imaging is highly statistical and, at this point, best analyzes the brain behaviors of groups of subjects, not an individual subject. However, Johnny and Jane will benefit if they are identified as members of a particular group of learners shown by neuroimaging to respond to a specific approach. Establishing the efficacy of multisensory teaching for children with dyslexia is an example of just such a research question.

Neuroimaging is not a panacea, only a tool. There always will be children who struggle to learn to read, independent of their general cognitive abilities. Educators will struggle to find the most effective methods for teaching these children. Neuroimaging, even as it advances, will not eliminate these struggles; but it will help reduce them, significantly. Is this a scenario from the pages of science fiction literature? I think not. It is a likely outcome of a research agenda that partners neuroscientists and educators to unleash learning potential in powerful new ways. But to translate that vision into reality — to go beyond science fiction, even beyond scientific findings — requires educators, researchers, and policy makers to work together. Maybe, to dream together, too. The possibilities shrink or expand with our vision.

Author's Note
Technical aspects of neuroimaging are complex, and like everything related to the brain, straightforward questions yield complicated answers inspiring additional questions and ever-more complex answers. Nevertheless, neuroimaging has furnished important insights about the brain and dyslexia. For this discussion, I have summarized, and in some cases, simplified detail to highlight salient points. For those who wish to explore more technical and complex information, sources for additional reading are provided in the Resources section.

SchwabLearning.org®
A Parent's Guide to Helping Kids with Learning Difficulties

The Expert Answers: Dr. Gordon Sherman

How is World View Affected by Dyslexia?

SchwabLearning.org asks:

Decades of scientific research show the brains of people with dyslexia are structured differently, work differently, and learn differently — compared to those without dyslexia. Does it follow, then, that people with dyslexia actually think differently? If so, how?

Gordon F. Sherman, Ph.D. responds:

Broadening Our Understanding

Regarding dyslexia through multiple lenses broadens our understanding. We examine the brain structure of people with dyslexia through high-powered microscopes. We use high-tech neuroimaging technologies to "see" how their brains function. And, we test them with a variety of psycho-educational instruments to understand how they learn. All these lenses contribute to our understanding, but no single lens is without limitations.

There is another lens through which to view dyslexia. It is not technical or statistical. Nor is it new, though it is very advanced. Its design is the result of millions of years of natural selection and evolution. I am talking about language. Language allows the brain to express itself through the mechanisms of speech and writing.

What follows is a written narrative from someone with dyslexia in response to the question, "How does your brain work and think?" It is important not to over-generalize from this material, to remember that this is **one** person's experience with dyslexia and that self-reporting, like all methods, has limitations. But this perspective, too, can provide insights.

Here then, is a brief journey inside the brain of someone with dyslexia. As you take this journey, think about the differences in structure, function, and learning in dyslexia. Think about the environment's role. Also, reflect on your own thinking process and on the thinking processes of people you know. How does your brain work and think?

Reflections on Thinking Dyslexic

"When I was young, I drifted in an alternate dimension — where entities like time, space, quantity, and words held value and nuance, but were not segmented or dissected into bits. These entities were ethereal wholes.

I was happy until grownups expected me to interact with the world in proscribed and systematic ways. Gradually, I understood that my peers knew secrets about the world that I did not, navigational secrets enabling them to sail through school with ease. But I was lost. By kindergarten, I knew I was an outsider. And, the world seemed frightening and oppressive.

How is World View Affected by Dyslexia?

Reflections on Thinking Dyslexic (continued)

As I grew older, I began learning the "secrets." But it was a struggle. The hardest required me to focus on minute detail, to perceive and remember intricate patterns and to associate these with speech, text, and mathematical concepts.
The importance people attached to the exact form and sequence of these configurations — these demon letters and numbers — perplexed me, almost as much as how easily everyone mastered the rules governing these complex little patterns. Everyone but me.

Sometimes I resisted learning the secrets about the patterns. My brain seemed unable to do and hold all the stuff everyone thought it should. I came to fear the word 'stupid' like no other. Better to be stubborn — or invisible. I learned to be both.

Later, I discovered that the small patterns were embedded in larger patterns — models and principles for organizing language, thinking, problem solving, and daily living. At first, I was slower to recognize these larger patterns, perhaps because so many were introduced in school, where my thinking and self-esteem were undermined by the tyranny of the tiny sequential patterns.

The rules of letters and numbers are ruthlessly exact! I was happier in the gray zone of literature classes or current events, where right and wrong were matters of opinion, where concepts and ideas flourished, and where flashes of insight did not require painstaking reconstruction of their steps of origin to have merit.

Seeing Around Corners

Eventually, I caught on to the secrets — the power of patterns, big, small, concrete, and abstract. I still struggle with little linear patterns, especially numbers (e.g., 9x9=extreme anxiety). And, when I scan lines of numbers and text, the information doesn't always register. Nevertheless, at some point, a transformation took place. I saw how all the parts and wholes relate.

Now I love patterns! I navigate oceans of material with patterns, applying the tool of linear thought to render wholes into matrices with infinite configurations, connections, and perspectives — endless possibilities! I see around corners, far ahead and behind, from above looking down, and from others' perspectives. This way of thinking enables me to explore an idea with multiple sets of criteria.

To my surprise, I discovered that sometimes I see things others do not. Some people are so grounded in linear thought they miss the multiple connections, perspectives, nuances, and possibilities. It is as if they see life's tiny brush strokes, but miss the magic — the whole of the impressionistic painting, the harmony of that painting hanging with others, and the symphonies of paintings yet to be hung together or even painted. For me, the magic is in all those wholes and possibilities. For me, the multiplicity of possibility is the wellspring of inspired and liberated thought — be it poetic or pragmatic.

How is World View Affected by Dyslexia?

Reflections on Thinking Dyslexic (continued)

Is this "dyslexic thinking"? Once I experienced dyslexia as being lost in the dimension of wholes. Then I learned the secrets — how to read and use the power of patterns, how to use the sextant of linear thought. With these tools, I learned to navigate the dimensions of parts and wholes. Now, I experience dyslexia as a perspective, albeit with some limitations. For me, **dyslexia is a way of seeing and thinking about the world and its possibilities**."

Dyslexia Provides Diversity in Perspective

To fully understand dyslexia, we must look through multiple lenses. A personal perspective is just one, and this is just one individual's perspective. Remember, people with dyslexia are a diverse group. Nevertheless, as this narrative suggests, there may be something distinct about the ways people with dyslexia think — something consistent with what scientists are discovering about the ways dyslexics' brains are organized and operate.

Certainly, the world is not neatly divided into dyslexic vs. non-dyslexic, matrix vs. linear, and forest vs. tree thinkers. Our cognitive profiles differ according to a unique melding of attributes resulting from a remarkable interaction between genetics, brain structure/function, and an ever-changing environment. No particular cognitive orientation is necessarily bad or good. Environmental context usually dictates the benefits and drawbacks of a set of traits. In a traditional educational environment, clearly, having dyslexia represents a disadvantage. On the other hand, there may be advantages in being able to "see around corners, far ahead and behind, from above looking down, and from others' perspectives."

Diversity is nature's gift. "Dyslexic thinking" might be, too.

The Expert Answers: Dr. Gordon Sherman

What is Your Vision of Dyslexia?

SchwabLearning.org asks:

As a neuroscientist and an educator, what is your vision of dyslexia? What key points should we understand?

Gordon F. Sherman, Ph.D., responds:

Four points are crucial:

- The brains of people with dyslexia are different.
- We can design educational environments to prevent or diminish reading disabilities in people with dyslexia and to elicit their strengths.
- There may be a connection between dyslexia and certain abilities.
- The toughest challenge in teaching students with dyslexia and others at risk for reading failure may be a product of the mind, not of the brain.

> "Can you imagine preventing failure in children with dyslexia? Can you imagine unlocking their potential? I can."

Let's examine each of these points. My perspective may surprise you.

Differences in Dyslexics' Brains

Decades of research show people with dyslexia have brains that are structured differently, function differently, and learn differently. Dyslexia begins with a complex gene-environment interaction that initiates developmental changes in the nervous system before birth. The result is an atypically organized brain that processes information in unique ways.

Microscopic analyses of the brains of individuals with dyslexia show structural variations in left-hemisphere language networks, symmetry between the left and right hemispheres, and, sometimes, changes in sensory systems. Neuroimaging studies support microscopic analyses and show characteristic and distinct functional differences in dyslexic subjects — less engagement of left-hemisphere language areas and more bilateral processing.

Finally, educational research catalogues a number of distinctive differences among individuals with dyslexia, chief among them are language system difficulties — weaknesses in phonological processing (producing/interpreting language sound patterns) and difficulties learning alphabetic skills (written symbols representing speech). These learning deficits set the stage for problems learning academic skills, which often lead to negative educational, emotional, and social consequences.

It is important to remember, though, that even with the consistency of findings about structural, functional, and learning disabilities, people with dyslexia are a diverse group. Dyslexia varies from individual to individual in the combination and degree of strengths and weaknesses due to the intricacies of brain development and countless environmental variables. These factors and overall cognitive capacity influence a person's ability to compensate for dyslexia. And, yes, **people with**

dyslexia can overcome its "disabling" effects. While dyslexia is brain-based and life-long, it is amenable to educational intervention.

Role of Educational Environments

Environmental variables play a key role in dyslexia. The educational environment can translate a distinct learning difference into a profound learning disability or it can offset neural weaknesses and encourage latent strengths to blossom into competencies and talents. Neuroimaging studies show that brain functioning in subjects with dyslexia can change in response to structured-language intervention, functioning more like the brains of non-impaired readers. This adds further weight to decades of educational research demonstrating that effective early instruction can prevent and diminish reading disabilities in children with dyslexia and forestall associated academic problems. Good news, particularly since structured-language instruction also benefits most learners!

The environment provides the context in which certain brain-based attributes not only are rendered good or bad but also are judged good or bad. Thinking about dyslexia from another perspective — as brain diversity — illuminates this point. Nature loves diversity. Diversity feeds evolution by permitting adaptability to various environments. Human diversity may be more than a politically correct principle. Certainly, parents and educators must recognize that dyslexia is a distinctly different brain organization that can be profoundly disabling, particularly in the context of poorly designed educational environments. On the other hand, brain diversity may benefit our species. History and science tell us environments inevitably change. Who knows what kinds of minds our species may need in the future?

Is dyslexia a biological mishap? Nature's design?

The Connection between Dyslexia and Certain Abilities

Having dyslexia does not preclude having strengths and exceptional abilities. In fact, people with dyslexia sometimes are gifted and accomplished. But are they gifted and accomplished in spite of their dyslexia or because of it?

Recently, a number of high-profile CEOs in business have discussed their school difficulties and personal experiences with dyslexia. So, too, have many artists and performers. Certainly, individuals with dyslexia excel in various fields at noteworthy levels. Do their talents surface more often in particular domains of cognitive function like the arts, business, athletics, medicine? Are certain gifts more commonly seen in people with dyslexia than in non-dyslexics? Is a particular brain design predisposed for developing singular talents as well as for encountering difficulties learning to read? Or is something else at work — an "I'll-beat-the-odds" drive born out of hardship or an attraction to certain fields and interests because doors to others are closed?

Many experts in learning disabilities (Rawson, Vail, West) have written about hidden strengths in dyslexia that blossom into gifts and result in great achievements. An infamous but unproven list of accomplished dyslexics circulates in the learning disabilities field and even includes a number of individuals diagnosed posthumously! Educators often mention remarkable abilities outside the language domain in their dyslexic students. None of this is scientific evidence, but it prompts intriguing questions.

Is dyslexia the unintended byproduct of a mechanism in nature designed to ensure cognitive diversity and talent? Or is our impression of characteristic gifts in dyslexia skewed because strengths stand in stark contrast to weaknesses? In the last years of his life, the eminent neurologist, Norman Geschwind, M.D., often discussed the relationship between giftedness and dyslexia, speculating nature may have strategies for creating giftedness that may have drawbacks.

What is Your Vision of Dyslexia?

> Making talented brains is not simple. Nature probably has adopted many stratagems for the achievement of this end. .. The methods which create giftedness may not quite succeed and as a result... may produce giftedness in some areas and, at the same time, problems in others ... (Geschwind, 1984)

The phenomenon of the savant, beautifully portrayed by Dustin Hoffman in the movie "Rainman," is an extreme version of the cognitive paradox of talents and deficits existing in a single individual. Is dyslexia, at least as manifested in some individuals, a milder version of this cognitive paradox? For now, anything beyond speculation is premature. And certainly, it is irresponsible to suggest that everyone with dyslexia will demonstrate exceptional talent.

Only rigorous scientific exploration can establish any connection between certain talents and dyslexia. Thus far, evidence supporting any dyslexia-talent connection has proven elusive — with a few fascinating exceptions. A series of studies explored the hypothesized spatial strengths in dyslexia. In batteries of tests designed to reveal such abilities, subjects with dyslexia did no better than controls and often did worse. However, in two studies, dyslexics performed a particular task (the Impossible Figures Test) just as accurately as controls, but **faster!**

Why? This task requires subjects to evaluate whether or not a particular configuration actually can exist. Do dyslexics perform more efficiently on this task because their brains process information more globally? Are there advantages to this mode of cognitive function? In this task at least, a global strategy may be better than a sequential, linear one.

The toughest challenge in teaching students with dyslexia may be a product of the mind, not the brain.

> The learning disabled are not simply byproducts of diversity. They are probably a more variable population than those without special disability, and while they may well contribute disproportionately to society, they often pay a high price for their talents. It is our task to outwit nature by preserving the high talents without the disadvantages. (Geschwind, 1984)

Many mysteries surround dyslexia, but there are no mysteries about what constitutes effective instruction for those at risk for reading failure. We now know what it takes to "outwit nature."

Effective methods for teaching reading and writing skills to children and adults with dyslexia do exist and incorporate several distinguishing features. These methods deliver a structured-language curriculum in a sequential, systematic, and cumulative way through a multisensory approach — offsetting language, sensory, memory, and motor/attention processing differences. Indeed reading research tells us that effective early literacy instruction for **all** children includes most of these elements. Such instruction embodies the principles of "universal design for learning," making curriculum accessible for all learners.

What is Your Vision of Dyslexia?

Research also tells us that **effective early screening and intervention can prevent or diminish reading disabilities** in children whose brain design predisposes them for reading difficulties. Imagine preventing reading failure in children with dyslexia! Reading failure has been dyslexia's most singular defining characteristic.

Unfortunately, circulating scientific evidence about what constitutes sound instruction is not enough to ensure children will receive it. Understanding the dynamics of school change and imparting essential competencies to teachers are among the conditions necessary for implementing effective research-based instruction for diverse learners. Time, money, and attitudes pose formidable barriers in fulfilling these conditions.

As a neuroscientist and an educator, I believe our toughest learning challenge is a product of the mind, not the brain. We disable our vision and cheat our future if we yield to the belief that we cannot alter learning environments to unlock potential and if we buy into the assumption that today's apparent limitations govern tomorrow's possibilities. Overcoming this mindset — this learning handicap — requires courage, tenacity, and imagination on the part of students, teachers, and schools.

We also can and must strive to identify and nurture strengths in children with dyslexia. Irrespective of the dyslexia-talent question, all children do have strengths and weaknesses. Strengths can be recruited as powerful avenues for instruction, and, in some individuals, may prove to be superior talent.

Can you imagine preventing failure in children with dyslexia? Can you imagine unlocking their potential? I can.

SchwabLearning.org
A Parent's Guide to Helping Kids with Learning Difficulties

The Expert Answers: Dr. Gordon Sherman

Resources & References

Structural Brain Differences in Kids with LD

Books
The "B" Book - Basic Facts about Dyslexia, Part I: What Every Layperson Ought to Know
http://interdys.org/servlet/bookstore?section=OrtonEmeritusSeries
by Angela Wilkins, Alice Garside, and Mary Lee Enfield (Orton Emeritus Series)

The "D" Book - Doctors Ask Questions About Dyslexia: A Review of Medical Research
http://interdys.org/servlet/bookstore?section=OrtonEmeritusSeries
by Sylvia O. Richardson, M.D., and Gordon F. Sherman, Ph.D. (Orton Emeritus Series)

Understanding Dyslexia and the Reading Process: A Guide for Educators and Parents
http://www.amazon.com/exec/obidos/ASIN/0205309070/schwabfoundation/
by Marion Sanders

On the Web
The Brain and Reading (pdf)
http://www.sedl.org/reading/topics/brainreading.pdf
by Sebastian Wren, Ph.D.

National Institutes of Health: Children's Reading Disability Attributed To Brain Impairment
http://www.nih.gov/news/pr/aug2002/nichd-02.htm

The Environment's Effect on Reading Problems

Books
Parenting a Struggling Reader
http://www.amazon.com/exec/obidos/ASIN/0767907760/schwabfoundation/
by Susan L. Hall and Louisa C. Moats, Ed. D.

Straight Talk About Reading: How Parents Can Make a Difference During the Early Years
http://www.amazon.com/exec/obidos/ASIN/0809228572/schwabfoundation/
by Susan L. Hall and Louisa C. Moats, Ed.D.

On the Web
Proquest: Perceptions and Knowledge of Preservice and Inservice Teachers about Early Literacy Instruction
http://proquest.umi.com/pqdlink?index=0&did=000000080189497&SrchMode=1&sid=1&Fmt=4&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1059598653&clientId=19908

Resources & References

The Environment's Effect on Reading Problems (continued)

National Reading Panel Report Summary
http://www.nationalreadingpanel.org/Publications/summary.htm

SchwabLearning.org: The Expert Answers: Susan Hall on Reading and Parental Involvement
http://www.schwablearning.org/articles.asp?r=344

Whole Language Lives On: The Illusion of "Balanced Reading Instruction
http://www.edexcellence.net/library/wholelang/moats.html
by Louisa C. Moats, Ed.D.

Neuroscience's Role in Demystifying Dyslexia

Books
A User's Guide to the Brain
http://www.amazon.com/exec/obidos/ASIN/0375701079/schwabfoundation/
by John Ratey

Parenting a Struggling Reader
http://www.amazon.com/exec/obidos/ASIN/0767907760/schwabfoundation/
by Susan L. Hall and Louisa C. Moats, Ed. D.

Straight Talk About Reading: How Parents Can Make a Difference During the Early Years
http://www.amazon.com/exec/obidos/ASIN/0809228572/schwabfoundation/
by Susan L. Hall and Louisa C. Moats, Ed. D.

The Owner's Manual for the Brain
http://www.amazon.com/exec/obidos/ASIN/1885167415/schwabfoundation/
by Pierce J. Howard

On the Web
National Reading Panel: Report Summary
http://www.nationalreadingpanel.org/Publications/summary.htm

University of Massachusetts Medical School: Functional Neuroimaging (explanation of fMRI)
http://www.umassmed.edu/shriver/research/irc/cdcn/fmri.cfm

Neuroimaging's Potential Impact on Education

Books
The Secret Life of the Brain
http://www.amazon.com/exec/obidos/ASIN/0309074355/schwabfoundation/
by Richard Restak

Resources & References

Neuroimaging's Potential Impact on Education (continued)

References

Functional Disruption in the Organization of the Brain for Reading in Dyslexia
http://www.pnas.org/cgi/content/full/95/5/2636?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&author1=shaywitz&searchid=1011981781170_3730&stored_search=&FIRSTINDEX=0&fdate=1/1/1998&tdate=12/31/1998
by S E. Shaywitz, et. al. in *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 95, Issue 5, March 3, 1998

Cerebral Mechanisms Involved in Word Reading in Dyslexic Children: A Magnetic Imaging Approach
by P.G.Simos, J.I. Breier, J.M. Fletcher, E. Bergman, and A.C. Papanicolau in Cerebral Cortex 2000; 10:pp. 809-816

Developmental Dyslexia: Four Consecutive Cases with Cortical Anomalies
by A. M. Galaburda, G. F. Sherman, G. D. Rosen, F. Aboitiz, N. Geschwind in Annals of Neurology 1985;18:pp. 222-233.

Dyslexia: Cultural Diversity and Biological Unity
http://www.sciencemag.org/cgi/content/summary/291/5511/2064
(requires registration)
by E. Paulesu, et al Science March 16, 2001; 291: pp. 2165-2167. Reprints can be ordered.

Dyslexia's Affect on World View

Books

In the Mind's Eye: Visual Thinkers, Gifted People With Dyslexia and Other Learning Difficulties, Computer Images and the Ironies of Creativity
http://www.amazon.com/exec/obidos/ASIN/1573921556/schwabfoundation/
by Thomas G. West

Uniquely Gifted: Identifying and Meeting the Needs of the Twice Exceptional Student
http://www.amazon.com/exec/obidos/ASIN/189076504X/schwabfoundation/
by Kay Kiesa

Dr. Sherman's Vision of Dyslexia

Books

About Dyslexia, Unraveling the Myth
http://www.amazon.com/exec/obidos/ASIN/0935493344/schwabfoundation/
by Priscilla L. Vail

In the Mind's Eye: Visual Thinkers, Gifted People With Dyslexia and Other Learning Difficulties, Computer Images and the Ironies of Creativity
http://www.amazon.com/exec/obidos/ASIN/1573921556/schwabfoundation/
by Thomas G. West

Resources & References

Dr. Sherman's Vision of Dyslexia

On the Web
CAST: Universal Design for Learning (UDL)
http://www.cast.org/udl/

SchwabLearning.org: The Expert Answers: Priscilla Vail
http://schwablearning.org/pdfs/expert_vail.pdf

SchwabLearning.org: Dyslexia — An Overview
http://schwablearning.org/Articles.asp?r=43

SchwabLearning.org®
A Parent's Guide to Helping Kids with Learning Difficulties

E-ssential Guide

Visit SchwabLearning's Online Resources

SchwabLearning.org is a a parent's guide to helping kids with learning difficulties.

We'll help you understand how to:

- **Identify** your child's problem by working with teachers, doctors, and other professionals.
- **Manage** your child's challenges at school and home by collaborating with teachers to obtain educational and behavioral support, and by using effective parenting strategies.
- **Connect** with other parents who know what you are going through. You'll find support and inspiration in their personal stories and on our Parent-to-Parent message boards.
- Locate **resources** including Schwab Learning publications, plus additional books and websites.

SchwabLearning.org—free and reliable information at your fingertips, 24 hours a day, seven days a week.

Sparktop.org™ is a one-of-a-kind website created expressly for kids ages 8-12 with learning difficulties including learning disabilities (LD) and Attention-Deficit/Hyperactivity Disorder (AD/HD). Through games, activities, and creativity tools, kids at SparkTop.org can:

- Find information about how their brain works, and get tips on how to succeed in school and life.
- Showcase their creativity and be recognized for their strengths.
- Safely connect with other kids who know what they are going through.

SparkTop.org is free, carries no advertising, and is fully compliant with the Children's Online Privacy Protection Act (COPPA).

Schwab Learning is a nonprofit program of the Charles and Helen Schwab Foundation.