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A Sensory Fix for Problems in School

Certain learning disabilities are linked to problems of perception, when the brain misinterprets sensory input. Targeted exercises can help correct these difficulties

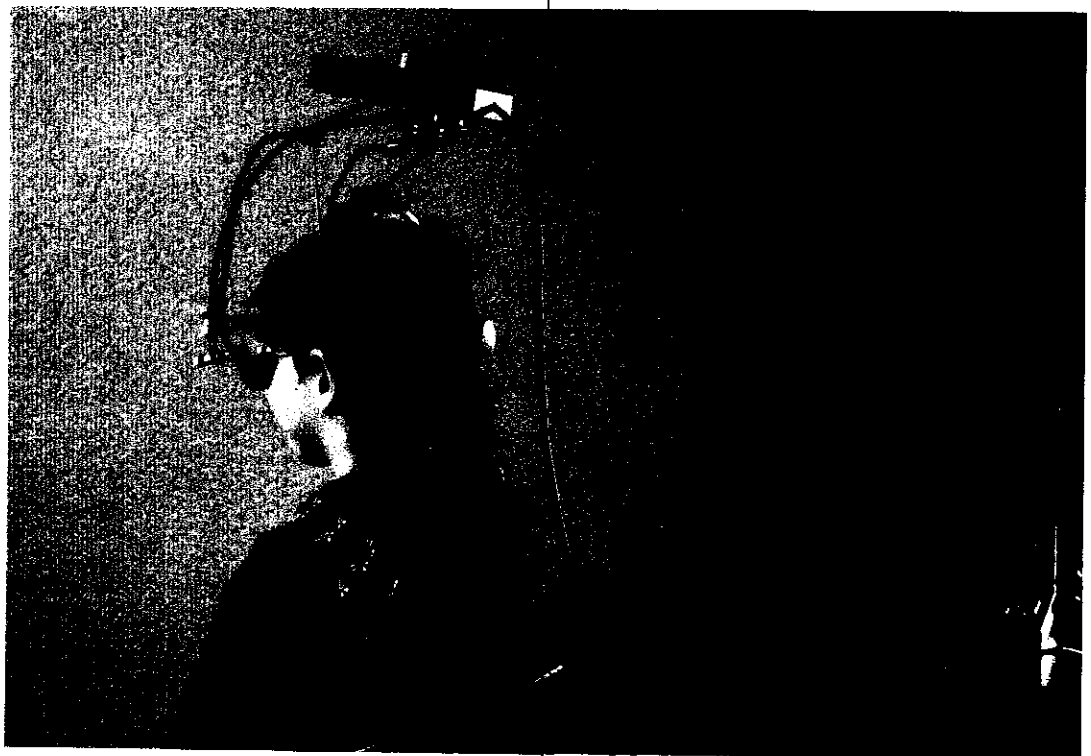
By Burkhart Fischer

To succeed in school, children must master the "three R's"—reading, writing and arithmetic—but not all students readily grasp these basic skills. Among English-speaking children, an estimated 2 to 15 percent have trouble reading or spelling, problems broadly classified as dyslexia. From 1 to 7 percent struggle to do math, a disability known as dyscalculia. Statistics vary; dyslexia appears to be more common, for example, among English speakers than among speakers of highly phonetic languages, such as German or Italian. Nevertheless, it is fair to say that at least one child in most elementary school classes in the U.S. suffers from dyslexia or dyscalculia.

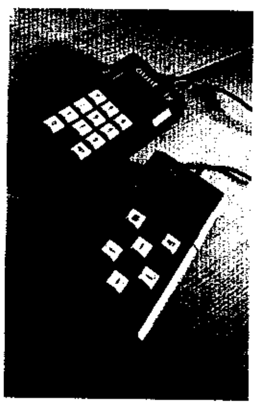
These learning disabilities defy easy explanation. Neither is the result of faulty eyesight or hearing, both of which can also delay language acquisition but are easily corrected using glasses or hearing aids. Instead children with dyslexia and dyscalculia have working sensory organs, apparently normal sensory and motor development and, sometimes, above-average intelligence.

After more than 15 years of research, investigators now believe these conditions frequently involve so-called partial functional deficits, often of the senses: in affected children, the eyes and ears accurately register sights and sounds, letters, numbers, spoken syllables—but that information is misinterpreted as it is processed in the brain. Curiously, girls apparently suffer from fewer partial functional deficits and seem less affected by disorders of sensory perception in general, although we do not yet know why this should be the case.

At the Optomotor Laboratory at the University of Freiburg in Germany, where I am the founder and director, we test children for sensory-processing errors, looking closely at what expertise the brain needs to develop before it can coordinate activities as sophisticated as understanding speech, reading or calculating. We have devised targeted exercises to hone these underlying mental skills. Our training can indeed help children to construe auditory and visual information correctly, and in so doing, it boosts their ability to read, listen, spell and do math.



The headgear-based apparatus at the right and the handheld devices below are just some of the tools that can help train kids to improve their control over perceptual skills essential for reading and other learning.



Building Eye-Brain Coordination

Seeing depends on our eyes only at the very start of a complicated sequence of processing steps. Along the way, various adjustments take place. For example, consider the fact that only a tiny area of the retina—several layers of light-detecting cells at the back of the eye—is capable of distinguishing visual details. To work around this physical limitation, the brain directs the eyes to make rapid movements called saccades, which enables us to shift our focus from one place to another. Without these jumps, we would never register more than a thin slice of our field of view. Reading, in particular, requires highly precise saccade control. When we read, our eyes skip from word to word between three to five times per second. The brain must be able to choreograph these movements such that our eyes scan words and syllables in the correct sequence without jumping ahead. For this kind of eye-brain coordination to take place, the areas of the brain responsible for language processing and for eye movements must be in perfect sync.

In 2000 our team at the Optomotor Lab explored the possibility that some children who have difficulty reading might also have poor saccade control. Working together with physicist Klaus Hartnegg, also at Freiburg, and physician Monica Biscaldi-Schäfer of the University Medical Center Freiburg, we asked 620 people between the ages of seven and 17 to perform two tasks measuring eye movement control.

First, the participants glanced away from an initial focus—a point of laser light—toward a second point of light when it appeared, and then, almost immediately, they had to look away from the new stimulus. This second "antisaccade" task is harder than it sounds because the natural reflex is to continue looking at the new light; without excellent control, it is hard to override that instinct. In this part of the test, however, any eye movement toward the second light counted as an error.

The results confirmed our ideas: subjects who read poorly also had significantly less control over their saccades than did nondyslexic children and

FAST FACTS
Training the Senses

1» **Learning disabilities such as dyslexia and dyscalculia may arise in part from faulty sensory processing.**

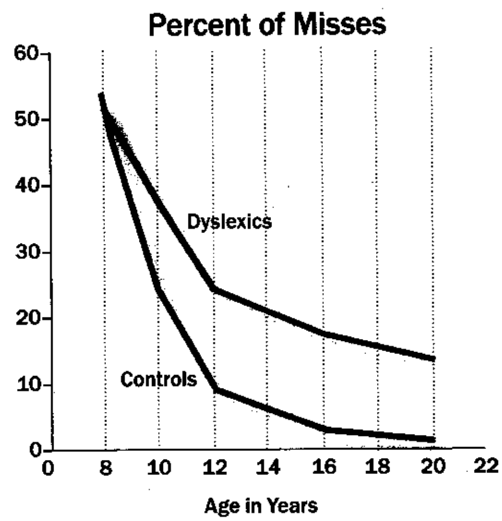
2» **Testing can identify specific sensory deficits: many dyslexics have trouble interpreting sounds; dyscalculics often show a diminished capacity to recognize quantity on sight, a skill called subitizing.**

3» **Targeted training can improve sensory processing, which in turn has a positive effect on reading, spelling and arithmetic skills.**

HANNA FUCHS *Gehirn & Geist*

adolescents. We concluded that trouble in controlling visual attention must at least partially contribute to some cases of dyslexia. After analyzing 3,224 children and young adults between the ages of seven and 17—a total that included the subjects in the study above—we further concluded that the brain seems to learn how to control visual attention over time. Seven- and eight-year-old participants, both with and without dyslexia, erroneously looked at the second light in our test some 80 percent of the time over the course of 200 trials; children at this age, dyslexic or not, cannot normally read with the speed or fluency of an adult (and these particular children had all just started to learn to read).

At age 20, however, when most people are fluent readers, nondyslexic individuals erred 20 percent of the time, on average, and quickly redirected any errant glances, whereas dyslexic test subjects continued to look the wrong way on the antisaccade task about 40 percent of the time and failed to correct those errors 14 percent of the time. The results show a dramatic improvement for both sets of individuals over the course of normal development, but whereas the control subjects advanced very rapidly toward reliable saccade control between the ages of seven and 18, the dyslexic subjects increasingly lagged behind [*see illustration above*].



Dyslexic individuals are more likely to make mistakes in a task that involves regulating small eye movements, which suggests that a lack of control over visual attention may contribute to some cases of dyslexia.

Trouble in controlling visual attention appears to contribute at least partially to some cases of dyslexia.

Fortunately, several studies, including our own, have demonstrated that training can have an impact on saccade control—and reading ability. We formulated a variety of exercises for dyslexic subjects, aged seven to 17 years old, to perform daily at home using a specialized computer device borrowed from the lab [*see illustration on opposite page*].

In one exercise, they used only their eyes to follow a symbol that rapidly changed direction on the device's small screen. When the symbol disappeared, the participants had to indicate, using arrow keys, the last direction in which the symbol headed. The speed at which the symbol tacked around the screen—which determined the difficulty of the exercise—slowly increased, as did the subjects' skill level. After three to six weeks, our recruits were significantly better at directing saccades. Of particular significance, after training, children in the program made half as many errors in reading as they did before.

The Spoken Word

The success of saccade training is encouraging, but there is more to dyslexia than poor gaze control. Many researchers believe that dyslexic children also have difficulty understanding the spoken word. In particular, some dyslexics appear to lack full phonological awareness, which is the ability to distinguish among speech sounds, such as the initial sounds b and g, or among similar syllables. Psychologist Wolfgang Schneider of the University of Würzburg in Germany has demonstrated that drills aimed at building phonological awareness can bolster children's reading and writing skills in general—and they specifically help children who may speak a language at home that is different from what is spoken at school. Among other activities, these exercises require children to find words that rhyme, to divide words into syllables and to break syllables into individual sounds.

Unfortunately, not all children benefit equally from these exercises. To develop phonological

(The Author)

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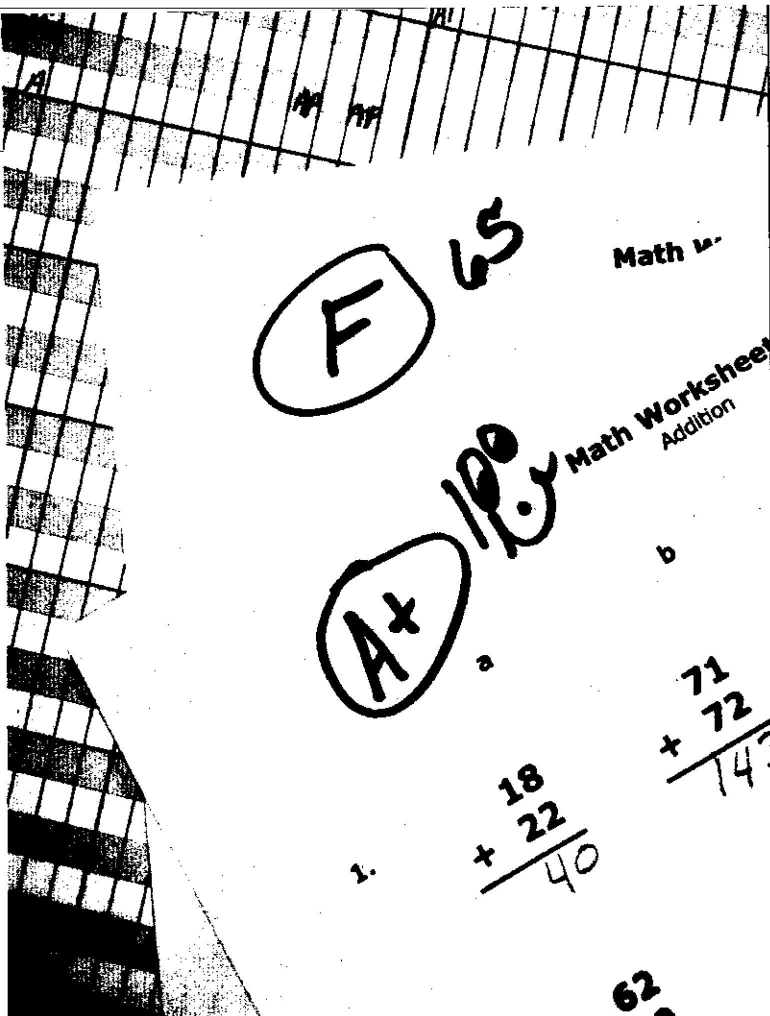

GETTY IMAGES

Research shows that even short, three-week training courses can improve arithmetic ability among dyscalculic children. Participants in one study made 60 percent fewer errors on a math test as compared with their score before training.

awareness, individuals must first be able to interpret speech; the sounds used in the training exercises are actual words and syllables. Some children, however, have trouble making sense of sounds long before they reach the brain's language center. Acoustic input undergoes many processing steps, and any errors along the way can cripple comprehension. In 2004, again in collaboration with Hartnegg, we developed a series of tests to probe which mental abilities are critical for understanding the spoken word.

Initially we focused on measuring our subjects' capacities for discerning volume and pitch. In the pitch test, for instance, children listened to two sounds at different frequencies; the spread between the two grew progressively smaller until the children could no longer say which was higher. We also tested how well our participants could recognize gaps. When we enunciate words, certain syllables or sounds are interrupted when, for example, the tongue briefly touches the teeth or our breath momentarily pauses. If a listener fails to perceive these breaks, he or she will hear a different syllable from what was intended.

Among the 682 children and adolescents we analyzed, we found a strong association between dyslexia and auditory-processing deficits such as discerning pitches, soft versus loud sounds, or gaps between syllables. Indeed, children with reading problems scored lower on all the tests we administered. As before, our subjects became increasingly competent up to about age 20, and so we concluded that the brain must learn to hear subtle differences among sounds over time. As with the saccade training, we devised a regimen to exercise auditory perception that included drills for distinguishing sounds by pitch and sound intensity, as well as perceiving phonetic gaps between sounds. The trainees practiced each task for 10 consecutive days, over the course of several weeks. One study of 509 students showed that this program markedly improved their ability to distinguish pitches. The drills also had a positive effect on spelling: participants made approximately 40 percent fewer spelling errors than before. By comparison, subjects who did not undergo training reduced their error rate by only 10 percent.

In 2001 neuropsychologist Teija Kujala and her team at the University of Helsinki in Finland revealed that perceptual training brings about permanent changes in the brain. They studied the effect of audiovisual training, which made use of various tones but no language-related sounds, on children who had reading problems. After seven weeks of practicing 14 different exercises, the students not only made fewer reading errors but also showed changed patterns of brain activity, as measured by electroencephalography. In particular, scientists observed more intense neuronal firing in the auditory cortex, a part of the brain dedicated to perceiving sounds, in response to anomalies in an expected sequence of pitches.

How Many?

Basic perceptual processes also play an important role in dyscalculia. Take, for instance, subitizing, or our knack of perceiving quantity just by looking, not by actually counting. This facility aids children as they establish a concept of number—namely, the idea that a numeral stands for a particular amount. Most four-year-olds can readily recognize quantities between one and four. But we hypothesized that children suffering from dyscalculia might be less able to subitize. Hartnegg, Optomotor Lab researcher Christine Gebhardt and I tested this idea in a study of 375 children and adolescents. We flashed at random anywhere from one to nine small circles on a computer screen. The circles appeared so fleetingly that it was impossible for our participants to count them; instead they needed to be able to identify the amount on sight and press the correct number on the keypad. We were particularly interested in response times.

Our results, published in 2008, revealed that individuals with dyscalculia were, as expected, less adept at subitizing and took considerably longer to come up with the correct number of circles. Fortunately, just as with acoustic and visual training, a person can enhance his or her ability to subitize by practicing his or her powers of estimation, looking at collections of dots or figures and guessing how many. Another study from our lab, also published in 2008, revealed that a three-week training course could improve subitizing—and arithmetic ability—among dyscalculic children. Participants who performed the exercises made 60 percent fewer errors on a math test as compared with their score before training. In contrast, a group of children who did not participate in the training showed no improvement. Our research further indicated that children extend their capacity to subitize throughout school. As is the case with hearing and seeing, subitizing—and presumably other perceptual processes as well—is continually refined into adulthood.

Regrettably, it is difficult for parents, teachers and physicians to discern whether a child's perceptual development lags behind that of his peers. To estimate the prevalence of perceptual problems, we extrapolated from our studies, determining the percentage of children among those with dyslexia or dyscalculia who scored below the control subjects on our battery of tests. Among the eight-year-olds with dyslexia or dyscalculia, 64 percent lagged behind in at least one perceptual function. And because these children develop certain perceptual capabilities at a slower rate than unaffected children do, this proportion increased with maturity: at age 16 some 85 percent of the children with reading and math difficulties displayed perceptual shortcomings as compared with the control group. Of course, if visual- and acoustic-processing faults were solely to blame for dyslexia or dyscalculia, the rate would have been 100 percent. Nevertheless, these faults clearly aggravate many cases of learning disabilities and deserve further investigation.

Researchers are planning to study preschoolers in the near future. Targeted training might then be used to mitigate the effects of visual- and acoustic-processing faults before children start to read. It also remains to be seen whether training can help very able pupils, who, as initial studies reveal, sometimes exhibit perceptual problems. For instance, they are frequently more reactive on tests of gaze control; instead of reacting too slowly, their eyes may react too quickly, which can also make reading difficult. Sensory-processing deficits appear to have the largest effect on special-needs students. In 2008, in collaboration with Sylvia Denecke-Fassrainer of the Kollegium der Kirchberg-schule in Herborn, Germany, I conducted a study at a school for special-needs students. We found that none of the 49 subjects, ranging in age between nine and 16 years old, performed at an age-appropriate level on the tests described in this article. Subsequent training improved academic skills in these children but less so than normally occurs in students without special needs.

It is difficult for parents, teachers and physicians to discern whether a child's perceptual development lags behind that of his peers.

Our findings have implications for the entire educational system. If 75 percent of all students diagnosed with dyslexia and dyscalculia probably also have sensory-processing problems—and if we assume that special training can strengthen at least one academic talent in approximately two thirds of cases—then we could dramatically help half of all dyslexic and dyscalculic students. Unfortunately, physicians look for disorders only in sensory organs; teachers know how to spot deficits in "higher" skills. Sensory processing falls into a gray area. Screening high-risk groups using the tests and exercises discussed in this article, however, is not only feasible, it would pay enormous social dividends in the long run. **M**

(Further Reading)

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