Verbal Bottleneck

People who stutter sometimes suffer from mistaken notions about their intelligence or emotional balance, but the problem is the neurophysiolocal processes of speaking itself.

By Katrin Neumann

Greg K. was only three when the problem began. During a family vacation he saw two crashed cars burning. Soon after that, his parents recall, the boy began stuttering. Even today, at the age of 40, Greg is more likely to order lasagna in a restaurant and forego his favorite pizza, capricciosa, because he cannot manage words that begin with explosive sounds like the letter *k*.

Speaking is precision work, yet most people merely have to open their mouths and a well-ordered flow of words pours out. In scant milliseconds the brain coordinates our speech apparatus so that it makes all of the appropriate sounds. The muscles of the larynx, tongue and lips work in unison, while air is metered out in exactly the right amounts. But for approximately 1 percent of all individuals who stutter, verbal communication requires more than a little willpower.

Whereas some people view stuttering as a personality disturbance or even as a sign of low intelligence, the difficulty lies in the act of speaking itself. Most stutterers can recite poems or sing with relative ease, but normal conversation can be a distressing exercise in frustration.

The disorder usually appears between the ages of two and four, is four times more common in males than females and often runs in families—genetics may responsible in 60 percent of cases. Emotions and stress also may influence the onset and durability of stammering. In recent years, researchers have untangled the related neurophysiological mechanisms as well.

Lazy tongue?

Speculation about the causes of the speech impediment has been widespread since ancient times. The Greek philosopher Aristotle, for example, declared that the tongue was the main culprit. He said that it was too lazy to keep pace with the human imagination—a mistaken belief with remarkable staying power. As late as the mid 19th century, physicians were using surgery to correct supposed defects in the tongue.

During much of the 20th century, stuttering was seen as a neurotic tic and a sign of deep psychological conflicts, thanks to Sigmund Freud and his successors. In this view, sufferers were trying to express suppressed desires. Still others suspected that it represented a form of learned anxiety behavior, provoked by the unsympathetic and angry reactions of listeners.

No doubt, environmental surroundings can play a significant role. Young children who unselfconsciously uttered the halting bursts of sound at home may find themselves the target of teasing when they enter nursery school. As a result, they may come to avoid talking as much as possible, which only increases their social inhibitions and isolation.

Greg K. finds it painful to recall his teen years. Tongue-tied and with low self-esteem he struck out with the in-crowd and in his attempts to make friends with girls. Military service was a nightmare: during roll call the recruits had to shout out their names. Greg hardly ever delivered his with the crispness required—and his surname begins with the dreaded *k*-sound.

Halting speech becomes more pronounced under stressful conditions, like face-to-face conversations. Conversely, fluency stabilizes if the stutterer is relaxed, or when an external pacemaker – such as the rhythm of a poem or song – ensures calm and order. Words may bubble up smoothly when speaking to an infant or a pet, or while asleep.

Compounding the problem, many stutterers suffer from secondary symptoms. As they struggle to spit the words out, they may make faces and gesticulate, deeply breathe in and out, blush or start to sweat. Unfortunately, most people react with irritation to such so-called parakinesis, which makes matters worse. When we interrupt, the stutterer's fear of speaking increases and he may withdraw in a huff.

Brain barrier

Neuroscientists began to explore how neurophysiological problems contribute to the disorder in the early 20th century. Neurologists Sam Orton and Lee Travis did path-breaking work in the 1920s that is still considered significant. Both men had observed that left-handed children experienced speech rhythm difficulties whenever they tried to write with their right, or nondominant, hand. Orton and Travis blamed defective lateralization: the brain fails to establish precisely which hemisphere is responsible for what function, resulting in neuronal processing errors that affect articulation.

Modern imaging techniques support Orton and Travis's idea. During the early 1990s, positron emission tomography (PET) demonstrated that stutterers exhibit less activity in the speech centers of the left hemisphere and in certain auditory areas than do non-stutterers, reported Joseph C. Wu, now at Stanford University School of Medicine, Peter T. Fox of the University of Texas and K. D. Pool of Irvine Medical Center. At the same time, the corresponding areas of the right hemisphere seemed to be unusually active.

A few years later a German-Finnish team headed by neurocognitive researcher Riitta Salmelin of the Helsinki University of Technology added precision to these findings. Using magnetoencephalography (MEG) to record the weak magnetic fields that form and continually change as a result of neuronal electrical activity, they found that signal transfers among speech centers in the left hemisphere were occurring in the wrong sequence. The cause was presumably defective neuronal connections.

Another contributor to stuttering is flawed sound processing. Understanding speech is critical for proper speech production [*see illustration*]. The so-called Wernicke's area in the cortex of the left hemisphere, which is involved with language comprehension, together with the rest of the auditory cortex, gives us constant feedback on whether our spoken words sound correct. The sounds we hear are constructed into meaningful words and sentences, and their correct articulation is planned in Broca's area, in the lower left frontal lobe. The nearby motor cortex then activates the necessary muscles in the tongue, larynx and lips.

Stutterers may be unable to perceive their spoken words correctly, suggest Janis and Roger Ingham at the University of California at Santa Barbara and Peter Fox at the

Health Science Center at the University of Texas in San Antonio. According to their PET studies published in 2003, Wernicke's area seems particularly affected, as are other areas of the brain responsible for hearing.

Last, stutterers exhibit structural weaknesses in the brain's speech motor centers and auditory areas. Neuroanatomist Anne Foundas at Tulane University in New Orleans in 2001 observed abnormal fissures and size relationships in areas of the cerebral cortex. In addition, neuroscientists Christian Buechel and Martin Sommer at the universities in Hamburg and Goettingen, discovered in 2001 that stutterers' nerve fibers were significantly altered in one area below the speech motor cortex. The researchers used diffusion tensor imaging, which detects slight changes in neuronal connections.

Compensating in the brain

In spite of these deficits, a fair number of stutterers exert some control over their handicap. Their brains naturally seem able to compensate for the flaws to some extent, and they improve further when aided by therapy [*see "Therapies that Work"*]. This balancing out appears to occur spontaneously as a result of the increased brain activity that occurs in the right hemisphere during speech. Using the scanning techique called functional magnetic resonance tomography (fMRT), our team, including physicist Christine Preibisch of the University of Frankfurt and neurophysiologist Anne-Lise Giraud of the University of Paris-Sorbonne, identified increased activity in one area, the right frontal operculum (RFO). The RFO is located in the lower frontal lobe of the right hemisphere and corresponds to the position of Broca's area in the left.

Normally, people seem to use the RFO when they recognize grammar mistakes and correct them, or when they are called upon to understand sentences with gaps. In contrast, the brains of stutterers apparently use it to restore lost function due to their left-sided deficit. And indeed, the less our test subjects stuttered, the more we saw evidence that neurons in the RFO were firing.

What mechanism switches on when a stutterer learns to speak still more fluently with the help of treatment? To answer this question, our team in Frankfurt joined forces with psychologist Harald Euler from the University of Kassel and with Alexander Wolff von Gudenberg. In the 1990s these two researchers developed a modified version of the American precision fluency shaping program. With the so-called Kassel stuttering method, clients learned a new, softer way of speaking and a special breathing technique. Even two years after treatment, stuttering incidence remained some 70 percent lower in more than three quarters of participants compared with baseline values.

We undertook an fMRT study at the same time to determine exactly what happened in those participants' brains. We documented the brain activity of right-handed male stutterers as well as that of a control group both before and immediately after treatment [*see illustration*]; we also followed up two years later.

At the outset of therapy, overall brain activity in the stutterers was somewhat higher than that of non-stutterers. As expected, the effect was particularly marked in the right hemisphere and specifically in the right frontal operculum. We also noted decreased activity in the left hemisphere's speech motor cortex and in Broca's area, supporting earlier work.

However, after therapy the situation changed. During speech, the increased brain activity migrated to the left side, close to the speech motor cortex, Broca's area and the auditory cortex. With speech therapy, the brain creates a more successful mechanism of compensation. The question is, did such therapeutic approaches actually "repair" the original speech centers that were less active in the first place? The answer is, unfortunately, no. Rather, the surrounding regions made up the processing difference; the areas that were less active at the start of the study continued to fire at about the same rate.

Thus, stutterers' brains naturally attempt to shore up their weaknesses by leaning on the RFO or, after therapy, by using the surrounding regions of the left-side's speech and auditory centers. This theory is supported by the observation that people who stutter only slightly usually exhibit more brain activity in the RFO than do severe stutterers, whose brains have been more successful at bypassing their sluggish areas.

In addition, the increased activity in the right hemisphere subsided to a certain degree in stutterers two years after their Kassel-method treatments ended. Their stuttering increased slightly at the same time. We interpret the overall generally higher brain activity in those who have had therapy as a sign that the new speech pattern has to be constantly monitored and practiced and is not completely automatic.

My research is now focusing on how effective, lifelong compensation works in the brain. One of the questions that interests me is how the brain activity patterns of people whose childhood stammering has subsided differ from those of people who continue to stutter. While researchers like me continue the search for answers, one thing is true. The earlier one recognizes the signs of stuttering, and the sooner therapy begins, the better the chances of long-term success at correcting it.

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Further Reading

Cortical Plasticity Associated with Stuttering Therapy. Katrin Neumann *et al*. Journal of Fluency Disorders, January 2005.
Stuttering: An Integrated Approach to Its Nature and Treatment. Barry Guitar. Lippincott Williams & Wilkins, 1998.
The Stuttering Foundation, www.stutteringhelp.org
The Stuttering Homepage, http://www.mnsu.edu/comdis/kuster/stutter.html
National Stuttering Association, http://www.nsastutter.org/

(infographic)

The Speech System

{labels}

Broca's motor speech area (pre-motor cortex)	Motor cortex	Wernicke's area (sensory speech center)

Normal process

The individual steps involved in speech production occur in a precise sequence. Broca's motor speech area in the lower left frontal lobe [*orange*] sets the process in motion and transmits sound units to be spoken into speech motor programs. The motor cortex [*green*] then directs the organs of articulation [*arrow 2*] such as the larynx or the tongue. During speech, constant self-monitoring occurs [*arrow 1*] via auditory areas like Wernicke's area [*blue*].

Before and After Therapy
Before treatment [*left*] a stutterer's brain exhibits comparatively more activity [*red*] in the right hemisphere, particularly in the right frontal operculum (RFO). In contrast, less activity [*blue*] occurs in the areas of the left hemisphere that relate to speech. Broca's motor speech area is particularly affected, a clear indication of functional weakness in this area. Accordingly, stutterers compensate for the left-sided speech center deficit by way of the RFO.

After therapy [*right*] the left hemisphere demonstrates increased activity. Areas close to Broca's motor speech area and other motor speech centers are particularly active during speech [*red*]. Therapy participants are able to speak almost fluently immediately after treatment. The lower level of activation in Broca's motor speech area persists [*blue*]. In general, the brains of those who have undergone therapy activate considerably more during speech, because maintaining the newly learned speech patterns requires constant monitoring.

(text box)
Therapies that Work

The earlier any treatment for stuttering begins, the better its odds of success. Whereas adults often make do with temporary fluency improvements after therapy, programs that start in childhood frequently can eliminate the speech impediment for good.

Numerous options are available to treat communication and speech disorders. However, only a few of these have been thoroughly researched. Two methods have proved particularly successful.

In the first, stuttering modification therapy, stutterers learn what is called pseudo-stuttering: they are instructed to stutter on purpose, which lets them confront their tics in such a way that they come to no longer fear them.

Fluency shaping, the second method, teaches stutterers new speech techniques. The Lidcombe program, a type of behavioral therapy developed in Australia that is custom-tailored to each child, is one variation. Another was developed by German researchers Harald Euler and Alexander Wolff von Gudenberg, a modified version of the precision fluency shaping program created by Ronald L. Webster of the Hollins Communication Research Institute. This treatment begins with a three-week period of intensive therapy in which stutterers learn a new speech pattern. They practice techniques such as stress-timing, soft voicing, smooth transitions between sounds and breathing. Follow-up exercises continue for a year. The long-term successes are impressive: more than two thirds continued to speak significantly more smoothly even after two years.

"Indirect" forms of therapy can help bolster chances for success as well. They focus on educating the parents of stutterers, and on helping them to change how they talk to their children. For example, parents learn to avoid speaking rapidly and not to use overly complex sentence structures.—K. N.