

Voices Lost and Found

Heidi Moss Erickson



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JOHAN SUNDBERG ONCE DESCRIBED THE VOICE as “the mirror to our soul.”¹ As singers we express musical gestures and text through our voices. We also reveal a profile of sounds, feelings, and emotions as unique as a fingerprint. Our voices are the most powerful instrument and the essence of our identities; but we can also take them for granted.

Those who have struggled with vocal injury, even temporarily, know the pain of that loss. Thankfully, there is a wealth of vocal experts, doctors, and speech-language pathologists to help singers through physical challenges. Vocal health education is a deservedly thriving field, and this journal has devoted many pages to various topics from some great minds like Robert Sataloff and Ingo Titze. There are of course tragic situations where cures could not be found; Julie Andrews comes to mind. However, science has evolved to treat even severe cases like Adele’s vocal cord hemorrhage. Innovations from the surgical and rehabilitative realms are revolutionizing treatments of the voice, and even material science has devised ways to repair and regenerate damaged vocal fold tissue.²

But there is a class of vocal loss that extends beyond the structural level. The voices themselves are intact: no damage to the folds, no overt trauma to the mechanism. Instead, the challenges result from errors in the complex signaling of the brain to the vocal instrument. In these cases, a doctor cannot just look through a scope to diagnose the issue. The pathways are unseen, and for that reason, the approach must be customized through trial and error. It is only through specialized motor practice and experience that real change can occur. It is slow, and at times tedious, but the end result is that the brain adjusts to its new situation. Singing returns to these individuals with time, and although it may never be what it once was, it is nonetheless a gift.

Humans are capable of remarkable change. In 1880, William James talked about “plasticity” in his iconic *Principles of Psychology*, noting that our behaviors as adults are adaptable.³ But this principle did not apply to the brain itself. As recently as the 1970s, neuroscientists believed that the brain’s structure and function was fixed in adulthood, and that changes occurred only during early critical periods during childhood.⁴ However, since then, research has shown the brain’s remarkable ability to modify, change, and adapt via experience throughout our lifetimes. The term for this is “neuroplasticity,” a homage to William James’s early observations. Neural networks, like busy highways of electrical and chemical signaling, are the main players in adapting to circumstance via growth and reorganization. This allows the brain to rewire previous functions through different pathways in order to optimize or gain a new function.⁵ These changes range from new neuronal connec-

tions, to larger systematic adjustments, like cortical remapping (e.g., an entire brain area taking over the function of another). These circuit changes can result from learning,⁶ practice,⁷ environmental influences,⁸ and even psychological stress.⁹ We can therefore capitalize on neuroplasticity in our journey as singers and even conquer embattled circuitry.

The stories below, starting with my own, chronicle the ways neuroplasticity contributed to the rebirth of a singing voice. The results in each case were transformative, and I am grateful that the lessons learned in my own journey generated a template to benefit others. There are no words to express the gift of singing, and when it is lost, the pain is unimaginable. These three personal histories give a small window into how brain science healed lost voices. They are told from a more first-hand, casual perspective than previous “Minding the Gap” entries. I focus on the details from my personal journey to inform those of my inspiring students that follow. In celebration of World Voice Day 2023, those voices serve as an important reminder that all voices matter, and deserve to be found.

STORY 1: HEIDI MOSS ERICKSON AND THE CASE OF MIS-WIRED NERVES

I was that kid. You know, the one who would mug for the camera when anyone yelled “cheese!,” the who would dance wildly as a child when her dad would play Pink Floyd (true story), and of course, who was the loudest in the room when the “Happy Birthday” song broke out. But when I grew up there weren’t many role models in the performing arts. My large family prioritized the medical and academic sciences, and as the youngest of six, that is what I thought a “career” was. Music, on the other hand, was more on the “hobby” side of things. Like that lady who played guitar in church. Something I could do for fun when I had a moment of free time. That construct made sense in my brain.

Of course, the conflict of my “what I actually love” vs. “what I think I should love” caused a great deal of inner turmoil: at age 16, I was hospitalized for depression, a battle I have both struggled with and conquered back and forth for my entire life. Of course, my habit is to take anything difficult and turn it into a “teachable moment,” so I learned a lot about mood disorders, neurophar-

macology, different kinds of therapies, and became a lifelong student of the brain. Throughout my combined biology and music education, I took many neuroscience classes. I participated in studies while working in the lab and singing at night. I eventually was able to leave science and engage in a full time performing career. But the struggle never really resolved itself—and thus, science and music were inextricably linked in my being. Then, my world came crashing down . . .

In early March of 2007, in the eighth month of a stressful pregnancy, I woke up to brush my teeth and couldn’t spit. I looked in the mirror and saw an unrecognizable image. I thought I had a stroke. I drove myself to the ER and was reassured that I just had a case of something called Bell’s Palsy, an acute injury of the seventh cranial nerve (Figure 1). I was told it usually resolves in a few weeks; 85% of cases heal completely and nerve damage is generally minimal. Nerves are like wires: they conduct information through the axon and are coated with myelin, which acts like the white plastic coating on your phone charger. Most cases of Bell’s Palsy involve either a smaller portion of the nerve branches or just the myelin sheath, leaving the actual nerve intact. I was given steroids and an antiviral medication just in case and told not to worry.

I looked horrific—droopy and expressionless. Time went by, and after three months of no change, it was time to call the doctor. This was not the “gone in a few weeks” prediction I had been given. I vividly remember that first visit with the neurologist when the MRI results came in. He didn’t say anything, just that he wanted to do some EMG tests on my face to measure muscle activity. Once the electrodes were positioned, I recall seeing nothing on the monitor. Zilch. Like the machine was unplugged or possessed by a ghost. The neurologist looked serious. “Heidi, I hate to tell you this, but the damage is severe. One of the most severe cases I have ever seen. There is complete nerve death of all of your major facial branches. And the MRI showed the origin point being very high up close to insertion. The prognosis is not good. I am sorry.”

“I am sorry.” I heard those words in so many ways that day: I am sorry you lost your face. I am sorry you look so ugly. I am sorry you have a speech impediment. I am sorry strangers will stare. I am sorry your social interactions will be awkward. I am sorry you cannot perform

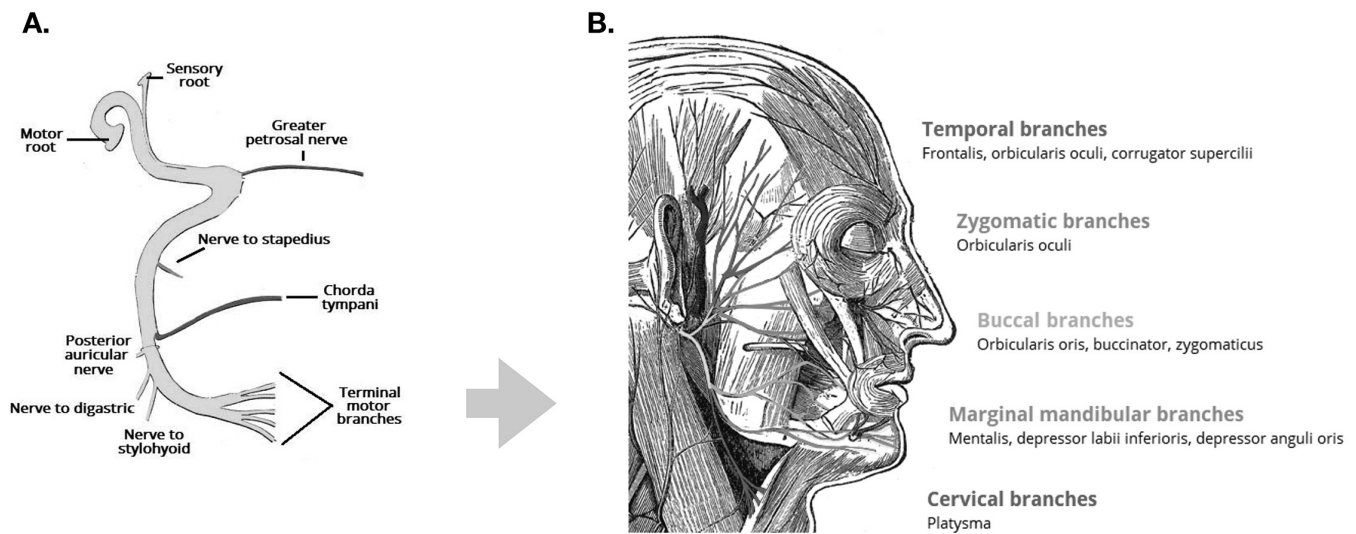


Figure 1. Schematic of the VII Cranial Nerve (facial nerve); (A) gross structure, (B) motor branches (image credit: TeachMeAnatomy).

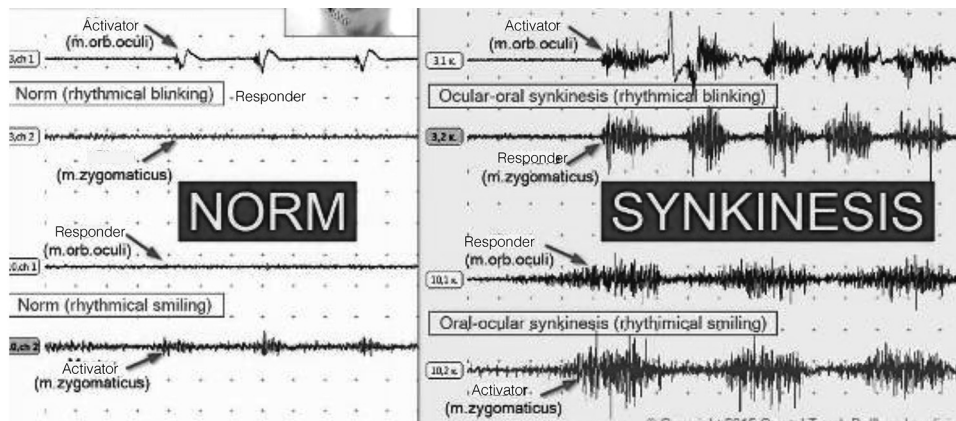


Figure 2. Synkinesis. Comparison of electrical activity in the eye muscle (orb. oculi) and smiling muscle (zygomaticus) between normal and synkinetic profiles. Activator: muscle signalled to contract; Responder: corresponding muscle not signaled to contract (image credit: Crystal Touch Bell's Palsy Clinic, adapted by Heidi Moss Erickson).

anymore. I am sorry you lost the top of your singing range. I am sorry this will change your life.

For 18 months I was a bit of a hermit, and I certainly didn't sing; my speech was already quite compromised. That stage of palsy is a total loss of facial function. But as the nerves regrow slowly, about a millimeter a day, the spasms begin. The nerves at that stage are like energetic puppies, contracting more enthusiastically than before. They wander into muscles they shouldn't, cross-connecting areas that have no business interacting. Nerves do not have a path when they regrow; it is mostly

chaotic and random. The end result is called synkinesis (Figure 2) and can present greater challenges than the initial paralysis. It is somewhat counterintuitive, but the long term issue with facial palsy involves random contractions which generate both aberrant movement and immobility, not paralysis. For example, I cannot raise my eyebrows due to the constant antagonistic muscle action, not because it is frozen. My eye squints when I try to smile, contracting my cheek but not allowing it to pull up the corner of my mouth. This leads to painful hypertrophy—like having a mini Arnold Schwarzenegger

pumping iron on your face. The differences between loss of nerve function and hyperactive mis-wired nerve function are easily apparent in the smile comparison from paralysis to synkinesis (Figure 3).

How does this impact singing? Facial expressions are the most obvious; my ability to act as a flirty soubrette or emotional lyric soprano were immediately gone. So even if I could sing, the idea of convincingly portraying a character on stage was far-fetched. My pronunciation was muddy; the lips are severely compromised, along with tongue and jaw elements. Articulator coordination is essential our art, shaping vocal tracts and enunciating text to create a diverse palette of sounds. Mine felt like they were put in big box and violently shaken up and I couldn't find anything.

Two suprahyoid muscles, the posterior digastric and the stylohyoid, are also innervated by CNVII (Figure 4). These muscles assist in elevating the hyoid bone during swallowing, and in my case, some of the spasms would induce scary choking episodes. As a classical singer, laryngeal stability is essential, and I had no idea how this would impact my instrument in the long term. I know that I had lost about a perfect fourth of my upper register, perhaps due to laryngeal asymmetry or inhibition of cricothyroid movement. Interestingly, there is one other known singer who had a similar experience: the great lieder tenor of the mid twentieth century, Aksel Schiøtz, had a surgical procedure for an acoustic neuroma that damaged his CNVII.¹⁰ In the book *Our Schubert*, David Schroeder writes that the surgery "should have put an end to his career in 1945, since it left him paralyzed on one side of his face and neck; but with the encouragement of friends and loved ones over the years, he relearned how to sing, becoming a baritone instead of a tenor."¹¹ So I wasn't the only one to lose high notes. But what is a soprano without high notes? How could I gain any of these functions back? I had wished Aksel left me a protocol to follow.

Our motor behaviors are generated from a kind of "body map." Through experience, our brain gets a sense of where things are in space and can predict accordingly. Babies start this process early, like grabbing for objects or babbling. They are creating a template in their brains for how things move. Those actions subsequently generate a complex algorithm to calculate future movements with better accuracy.¹² At this point in my injury, I was func-

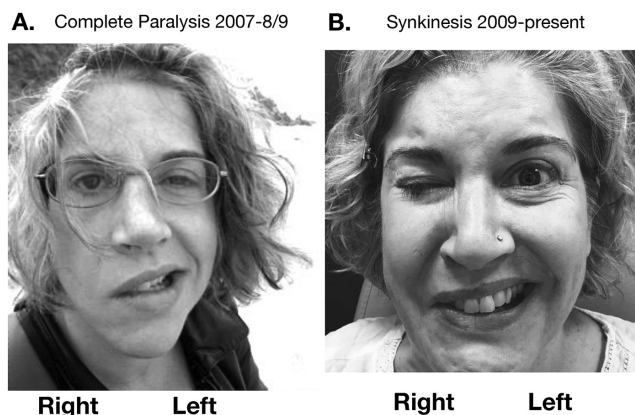


Figure 3. Comparison of right side facial paralysis (A) versus synkinesis (B) while smiling. In A, the unaffected eye is squinting due to blinking when the camera flashed; the paralyzed eye is unresponsive to blinking signal. Conversely, the same eye years later affected by synkinesis; the eye squints (without complete lid closure) when trying to smile (image credit: Heidi Moss Erickson).

tioning at a pre-baby level; my map was gone and I was desperately looking for it. My brain tried to fire signals to muscles that were either no longer there, in completely different locations, or already contracting feverishly. It became my passion to rewire my body map so I could sing again. In order to activate my own neuroplasticity, I returned to the habits I learned as a scientist.

My first foray into the scientific literature led me to papers on how my face would emotionally traumatize and stunt my infant daughter's development. (Side note: it didn't, disproving a lot of the literature back then. I now know emotional imprinting is more than a face.) I then stumbled upon a wealth of neuroscience literature in an unusual place, phantom limb patients.¹³ There are certain analogies between the two situations, each involving a visual and tactile component: the brain is interacting with the former setting, sending signals for pain and movement to areas that no longer exist. I thought I could use some of the sensory strategies used by these patients. One interesting technique involved mirror therapy. By placing a mirror in the center of my face, and observing the reflection, the brain sees the "healthy side" in the place of the loss. It would then try to send signals to match.¹⁴ I had some small successes, but not the results I desired because, unlike limbs, so much of our facial movements are coordinated bilaterally.

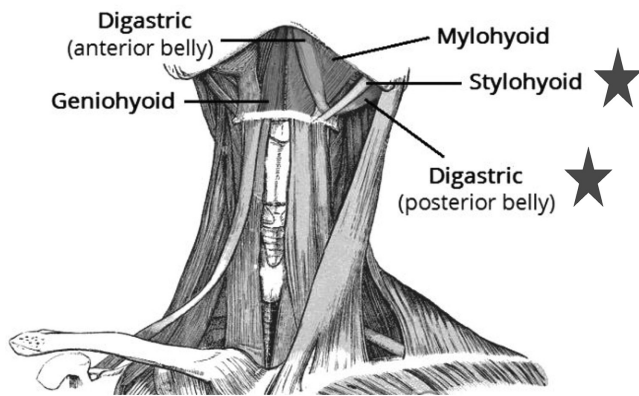


Figure 4. Suprahyoid muscles innervated by CNVII, stylohyoid, and digastric (image credit: TeachMeAnatomy).

My focus turned to how the brain signals the vocal mechanism itself. This led me to the wonderful world of vocal learning. The first installment of “Minding the Gap” described this feat of convergent evolution, and it was through a deeper understanding of how the brain signals the voice and articulators that would be my ticket to singing again.¹⁵ What amazed me as I unpacked this process was how much was happening behind the scenes in my brain. I could generate neuroplasticity and change my signaling map simply by incorporating many of the auditory-to-motor processes we all utilize when first learning to sing. The most sensitive place to focus my attention was the step that recruited the necessary muscles (near Broca’s area), and the toggling via the arcuate fasciculus to confirm that equation (Figure 5).

In the lab, we must always consider fixed versus variable elements in executing experiments, so the early phases were simple and reductionist. Patience was essential, and in order to keep the process on track and not give up, I tried to make it fun. I started with the most challenging consonant, [p]. (One doesn’t realize how many [p]s exist in our language until you cannot say it.) I would sit in front of a mirror for what felt like an eternity and hear different words with [p] in my head: pat, prop, happy, hop, Papagena . . . I wouldn’t say them at first. I would just hear them and mouth the parts I could pronounce. I used a mirror to see what was going on, inserting a visual element into the equation. After all, the more inputs the brain can use for its algorithm the better. One day, it finally came out: “Papagena!” I can’t explain what happened exactly, but my brain does remember both the old way (which sounds more like a muddy [f]) and the new way, which sounded like a real [p]. I had cracked the code for that sound and the recipe was quite simple: take time to hear it internally in the most detailed way. Practice repetition and don’t worry about mistakes. The vocal learner paradigm. Over time, I rebuilt my body map with the different elements and started to sing. The old wiring faded into the background and the new circuits took hold. I knew it wouldn’t be a re-creation of my old self and voice: I had to be comfortable with the new version. Radical acceptance was the key psychological step toward regaining confidence

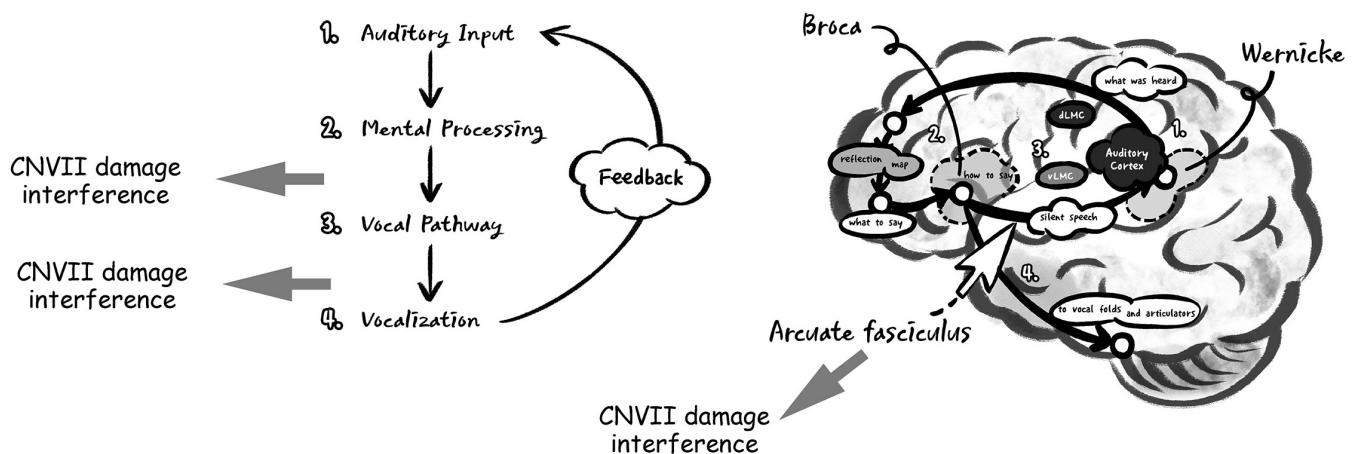


Figure 5. Areas of the vocal learning pathway impacted by CNVII damage (due to mismatching); also indicates rewiring areas (image credit: Kang Kang and Heidi Moss Erickson).

in my new voice. With that, I could sing again . . . and thankfully, I still do.

STORY 2: CARL AND THE COCHLEAR IMPLANTS

Back in the '70s, Carl (name altered for confidentiality) was a fixture in the San Francisco music scene. He played clubs with his smooth baritone, crooning songs like his favorite, "Fly me to the moon," with an uptempo flair. He performed with different bands, bouncing around and singing where he could, to an always adoring crowd. Some day, he hoped, he could make a real living doing what he loved, but for now, the small amount of money from these gigs was still extremely gratifying. He knew he was lucky.

By day he worked at the San Francisco International Airport to pay the bills. It was a good job. As a skilled technician, he spent a lot of time near the big planes working on various tasks that kept him mentally and physically challenged. He had a good balance between his work life and music life—until one day, that all changed.

Sometime in the mid 1980s, there was a huge explosion in one of the plane's engines. Carl was literally right next to it when it happened and he was lucky to have survived. When he woke up in the hospital, he found had completely lost his hearing. From that day on, he was to live his life as a deaf man.

The loss of his hearing meant the loss of his music, and that period of time became unbearable. There were episodes of depression and years of challenges living with this new reality. In the 1990s he became eligible to receive a 16-channel cochlear implant. This device bypasses the damaged cochlea to electrically stimulate the auditory nerve, providing information directly to the auditory centers in the brain. But 16 channels to compensate for the tens of thousands of hair cells in the cochlea meant that discerning pitches was still an impossible feat. The device was designed to accentuate speech frequencies, specifically vowel formants, and although that was an incredible leap for him, Carl still missed his music. Everything sounded cacophonous, even his own singing voice. So despite this revolution he still abstained from his former passion.

I met Carl in 2018 as part of a collaboration with the renowned Dr. Charles Limb at UCSF and Dr. Indre

Viskontas to formulate a hearing impaired choir. My task was on the pedagogic front, designing protocols to assist with pitch matching. I had just finished a paper on visual biofeedback in singing, and I thought it would be a great tool for this population.¹⁶ Due to hearing loss, particularly in congenital deafness, the auditory cortex and other association areas of the brain undergo compensatory plasticity.¹⁷ Thus, the auditory cortex can be redirected to serve other functions, like vision. Although Carl came to his impairment later in life, I thought a visual approach was worth a shot. Perhaps we could somehow connect his visual and auditory universes through neuroplasticity.

The protocol started with simple sustaining of speech tones and correlating them to what he saw on the spectrograph. We then went on to more complex pitch-matching relationships. Based on his audiogram, I filtered the input sounds on Voce Vista to optimize the signal and reduce competing background frequencies. In the beginning, he couldn't discern notes a major third apart. When he did make a match, he claimed he could not "hear" whether or not it was accurate. But with practice, he was able to achieve the target visually and become more confident in his singing (Figure 6).

On a whim, I asked him to sing his favorite song from back in the day. He was extremely hesitant at first, given the traumatic loss, but after a few months of working together, he felt comfortable enough to try. He chose "Fly me to the moon" since he had sung it hundreds of times in the past. It was note-perfect (I actually teared up . . .). But to him, the distortions from the cochlear implants made it sound completely off-key. When I told him it wasn't, he was shocked. I showed him on the spectrograph and he teared up too. So we decided to do some practice sessions where he would sing songs from memory wearing earplugs, minimizing conflicting feedback. His brain actually recalled the correct pathway: the motor signals from habitual memory were overriding the conflicting auditory feedback. His musical memory became another tool to add into the protocol.

Over the next few months, we played with permutations of these ideas, utilizing filtered inputs, memory, visual biofeedback, and motor learning to solidify his skills (Figure 7). There were moments where he said, "I can recognize that!," indicating a neuroplastic event where an auditory percept evolved.

When the program ended, I continued to touch base with Carl. He told me he had joined a non-hearing impaired choir and was so happy. In a two-year follow up, he shared an audio recording of a new song he had learned. This time, I really cried. It felt miraculous: When we met, he hadn't sung in over 25 years and here he is, singing again. Although there are still challenges, he can now discern some pitches within a major third and no longer needs continuous visual biofeedback. It is not a re-creation of his former singing self, but a new creation, one that is a model for all of us in his perseverance and love for music.

STORY 3: LANA, A STAR (AND VOICE) LOST

Lana (name altered for confidentiality) had traveled all over Europe singing lead roles in musical theater, classical, cabaret, and beyond. Her vocal talent knew no bounds, spanning genres with great ease. She even performed in a stadium concert where tens of thousands had cheered her impressive vocalizations. She was beautiful, dynamic, and full of life. But like many women, something happened during those middle age years, stripping her confidence and stalling her career. She sought out specialists. Tried many different approaches. Nothing worked, and it was devastating. A random recommendation led her to me for a few consulting sessions—a

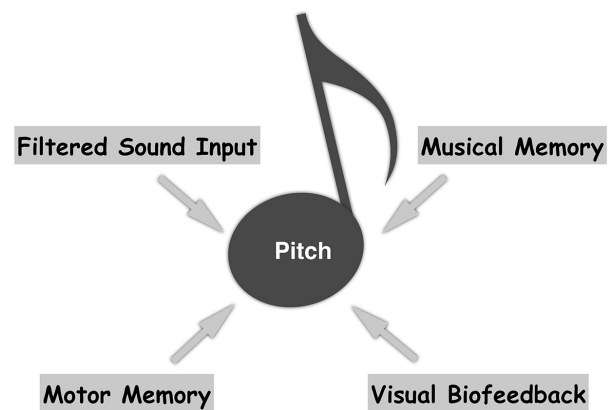


Figure 7. Multiple entry points to establish pitch matching for cochlear implant singer (image credit: Heidi Moss Erickson).

last straw of sorts—hoping that perhaps we could dive into neural elements to help her solve the mystery of her voice. What had happened that made something so easy suddenly become so overwhelmingly difficult?

There is a wealth of research on the impact of hormonal changes on the voice. The book *Singing through Change*, written by my dear colleagues Joanne Bozeman, Nancy Bos, and Cate Frazier-Neely, addresses the topic in a singer-friendly way. I recommended it to Lana and sensed her relief in knowing she wasn't alone. (It is one of the great gifts of our field that we can find community.) That psychic comfort was a big first step.

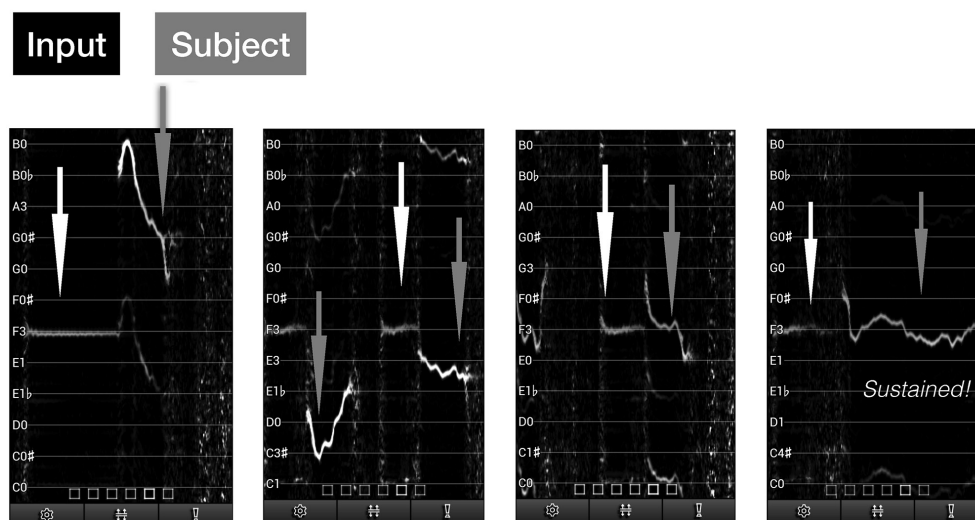


Figure 6. Visual biofeedback over time for pitch matching with cochlear implant. Input: F₃ on filtered piano or filtered male voice. Software = PitchLab display of fundamental only.

I often say, singing is a combination of physics, physiology, and psychology, with the latter being our most fertile enemy. When first listening to Lana, I didn't hear any of the requisite elements I had assumed would be present. There was no overt hoarseness, no pitch breaks, her middle voice seemed strong, and her range was not compromised. In other words, to me, she's still "got it." I asked about fatigue and dryness, and she did admit to experiencing those things that contributed to her trepidation about singing. I am not a voice therapist nor SLP, so I tend to tread carefully with anything that could be vocal health related. But since I didn't hear anything alarming, and she had the all-clear from her doctor to work with me, I moved forward with some ideas.

Just like our brain has a body map, it also has expectations. We are predictors by nature, and when we send a motor signal and receive an unanticipated outcome, we assume something is wrong. Imagine reaching for a cup of coffee, only to have it disintegrate in your hand like sand. That is confusing to a predictive brain. What I realized with Lana is that when she sang, her brain would suddenly realize, "Hey, that sound isn't what I expected," and then pull back and give up. To her, the voice had changed dramatically and it was so disturbing that it paralyzed her. Since I did not know her voice before, I had no frame of reference. To me, it was a healthy instrument and I couldn't figure out what was plaguing her.

She was very cautious in her approach, really tending technically to elements she thought were "off." I asked her questions about her sensations, feedback, and beliefs. Much of her concern revolved around her middle and lower voice which no longer felt strong and stable. In the past she could seamlessly travel between registrations, and now, there was hesitancy. She also sensed a wobbly vibrato, which I reassured her, I didn't hear. But in listening to older recordings, one could perceive a slightly different vibrational profile, which in her mind, felt like a canyon splitting her voice in two.

At this point, I realized my job was to change expectations. To shift the narrative from her voice being "broken" to her voice being "different." I used my story as an example, and reassured her that she could re-wire her brain to customize inputs to this slightly new, more mature configuration. When our brains try to send calculations from a previous paradigm, there will be error

messages. Her brain needed to get acquainted with her new voice. Not a bad, nor broken voice. Just different.

We decided to use visual biofeedback since that allowed her to uncouple from technical minutiae and just observe. What was interesting was that as she would sing, there was a moment where I could tell she was listening and "giving up." It showed as a sort of declination rate or fold destabilization event on the spectrograph where the voice would just drift off like it decided to stop before it was finished. I used different directives to continue the gesture beyond the phrase ("Pretend you are a preacher." "Imagine a stream of water flowing." "Draw a circle." "Intend beyond the last note."), or even just watching the spectrograph to continue the sound. Each had its own positive effect on the whole. The brain likes such varied inputs, and for Lana, it allowed for her voice to finally be recognized by her mind.

At the end of our sessions, she regained confidence and realized her voice was okay. The power of neuroplasticity conquered both the technical and the psychological. The last thing she did over Zoom was to perform one of her standards. It blew me away and I saw her smile for the first time. I don't know where she is now, but her star still shines brightly. Her voice, like mine and Carl's, will forever matter. And I am grateful to have been a small part of these voices being heard once again.

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with a focus on new music. She received her graduate degree in biochemistry with an emphasis in neuroscience. Her postgraduate research on telomeres at Rockefeller University led to prestigious publications, including a landmark paper in *Cell*. Heidi teaches vocal physiology at the San Francisco Conservatory of Music and applied voice at UC Davis. In 2007 she came down with a rare CNVII nerve injury which resurrected her passion for how the brain controls singing. Her courses and lectures have been featured both nationally and internationally at conferences and universities. www.heidimosserickson.com

The roofs are shining from the rain.
The sparrows tritter as they fly,
And with a windy April grace
The little clouds go by.

Yet the back-yards are bare and brown
With only one unchanging tree—
I could not be so sure of Spring
Save that it sings in me.

Sara Teasdale, “April”

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