II

LANGUAGE **GAINS**

4

THREE REVOLUTIONS

Language, Culture, and Biology

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Among the most daunting words in the English language has to be the word *but*. Though just a teeny-tiny runt of a word when up against the likes of such words as *truth*, *justice*, *tolerance*, and *diversity*, it has a power that can nonetheless arrest, derail, and alter personal history. Few mere mortals among us have escaped the dangling agony at the cliff of "I love you, but . . ." or have avoided the late-night despair when our child finally phones home sheepishly saying, "I would have come home on time, but . . ."—and so on and so forth. We pull ourselves together. We deal with it. We move on. This is not the "but" that breaks us. It is another "but" that does much more harm, a "but" that devastates, subjugates, and alters human history.

I have come to know this "but" well. As a scientist whose research spans the past three decades, I have met this "but" many times after lectures that I've given at scientific conferences reporting that signed and spoken languages are acquired by young children in identical ways, or that signed language in the brains of deaf individuals is processed similarly to spoken language in the brains of hearing people. I know well the polite gaze, the hushed tone of the retort "*But* . . . surely, speech is *better*." I have met this same "but" when teaching medical school students and talking with doctors. I have met it while talking to politicians, policy makers, and educators. I have even met this "but" when simply chitchatting with the person next to me on an airplane.

With much power, this "but" along with its sister phrase "speech is better" have impacted the world. Like Mutt and Jeff, the two have seemed inseparable, and they have fueled enduring views that are especially noteworthy because people expressing them are apt to note that they mean no harm, as what they are expressing is (to them) self-evident, logical, and true.

Is it?

I began asking this question years ago as my scientific data began revealing a pattern that wouldn't be shaken. Converging across multiple types of studies (behavioral and brain imaging), multiple populations (deaf and hearing; infants,

children, and adults), multiple signed and spoken languages (American Sign Language, Langue des Signes Quebecoise [LSQ, the signed language used among culturally French deaf people in Quebec and other parts of French Canada], Italian Signed Language, French Signed Language, and spoken English, French, Italian), and multiple countries (the United States, Canada, Italy, France), signed and spoken languages were somehow . . . the same. So what could "*But* . . . surely, speech is *better*" possibly mean? I asked myself. More to the point, what does "better" mean?

I reasoned that "better" could not mean that only spoken language is a "real" language and signed language is not—at least not anymore—as most educated conference participants that I've met (scientists, doctors, policy makers, educators, and the like) jump to acknowledge that, of course, signed languages are real languages. It also appears that "better" is not simply a reflection of the public failing to understand that deaf people have a unique culture. I have found that most colleagues readily offer their understanding that deaf people have a distinct culture. Instead, "better" appeared to mean *biologically* better, superior. On this view, speech is presumed to be biologically superior to sign. How could this be? Such an assumption should be either supported or refuted with careful examination of the experimental facts before us, or so I thought. And the facts before me were demonstrating that the assumption is wrong: sign and speech are represented and processed in largely equivalent ways in the human brain. Consequently, there's no basis for the "but . . ." In fact, I reasoned that the "but . . ." may be supporting unsupportable prejudice.

So the good scientist in me set out to test what I've come to call the "but" hypothesis: but . . . *is* speech biologically better? How could we know? How would we test this?

Scientific pioneers in history have faced the question head-on. For example, in his now-classic book on the biological foundations of language, Eric Lenneberg taught us that language-like behavior suspected of being part of our biological capacity should evidence regular development in the face of environmental vagaries, achieve mastery of the target capacity on a maturational timetable over development, and display other features involving the brain's neural tissue and its dedication.[1] The candidate behavior should also evidence differences from other capacities, perhaps even those that afford advantages.

In this chapter, I consider three revolutions in thought over the past fifty years that have provided science and society with empirical evidence regarding the prevailing assumption called here the "but . . . speech is better" hypothesis. Taken together, the three types of evidence do not support this hypothesis and instead provide a principled impetus for change—to change our minds and to alter the course of a misguided history.

They say that good things come in threes. Here, the three types of revolution-

ary thought include these: Linguistic analyses have demonstrated that signed languages are "real" languages. Cultural analyses have revealed that groups of deaf people around the world constitute cultures. Last but not least, biological evidence has demonstrated that signed and spoken languages are biological equivalent—not to mention the fact that aspects of visual processing and higher cognition in early sign-exposed deaf individuals are advantaged and enhanced as compared with the same aspects in hearing peers. Evidence from the collective revolutions in thought is clear: speech is not better than sign. Like a Gamma Knife, the power to cut out wrong and ill-fated material can come only when all rays—all three revolutions in thought—are aimed focally together.

Revolution 1: Language

Revolutions can occur in many ways. More than a half century ago, a revolution in human knowledge began. It was a quiet revolution. Following only three years after Noam Chomsky's famous publication of *Syntactic Structures,* in 1957,[2] this revolution started in 1960 with a single publication by a young man who, by profession, was a scholar in classical English literature, Chaucer in particular. He was also a professor at Gallaudet University in the United States, now a bilingual university for Deaf and hard-of-hearing students where the primary languages used are American Sign Language (ASL) and English. The professor's name was William Stokoe, and, by using classical linguistic analyses, he "cracked the code" for the "phonological level" of language organization in ASL.[3]

The discovery of a phonological level of language organization in ASL was noteworthy within the discipline of linguistics regarding the linguistic status of human signed languages. At the time, signed languages were viewed largely as "gestures" or "pictures in the air," lacking in any formal rules, underlying grammatical principles and regularities, and, crucially, sublexical organization that lie at the heart of human spoken languages. Indeed, signed languages were viewed as lacking in all that was required to be a "real" language. In the decades to come, the discovery of a sublexical, sign-based phonological level of language organization in signed languages would serve as a springboard for extraordinary discoveries about the biological basis of all language in the human brain. These discoveries would challenge our assumptions about the very nature and essence of human language in our species.

We now understand, of course, that the phonological level of language organization is found in all human languages, be they signed or spoken. This particular level of structure in human language is formed from a restricted set of bits and pieces of meaningless language units. These units are combined according to the rules of a particular language to make up the potentially infinite set of words or signs (and sentences) possible in spoken or signed language. In the case of spoken language, the restricted set of units comprises meaningless sounds, and in

the case of signed languages, the restricted set of units comprises meaningless hand forms in front of the signer's body (with restricted locations, movements, and orientations).

When Stokoe first invited me to be a researcher in his laboratory, in 1978, he was still passionately probing the linguistic regularities of ASL phonology, trying to crack the code for what types of variation are possible in its surface hand units (sign phones and sign allophones), and from which restricted set of underlying categories of hand units they are derived (sign phonemes). I came to Stokoe from Ursula Bellugi's sign-language laboratory at the Salk Institute for Biological Studies in La Jolla, California, where I had begun comparative language-acquisition studies of young deaf and hearing babies. I was en route to Harvard University, where I was going to conduct psycholinguistic and language-acquisition studies with Roger Brown and Noam Chomsky.

Stokoe and his students' insistence on the existence of a sign-based phonology (including his student Ben Bahan) and Stokoe's impressive reams of data and analyses were dazzling to me and would form a foundational impetus for my journey into the human brain to come. If the signed languages used by Deaf people were indeed part of the set of "real" languages of the world, Stokoe reasoned, then ASL had to exhibit the "phonological" level of language organization as well. It did. Following from Stokoe and his team's discoveries, four decades of formal linguistic analyses by thousands of linguistic scientists around the world have demonstrated that the world's signed languages, including ASL, Italian Signed Language, French Signed Language, LSQ, and other signed languages also have a "phonological level" of language organization that is identical to that of spoken languages.[4]

Beyond phonology, linguistic analyses have also laid bare the rich grammars of the world's natural signed languages, demonstrating that they exhibit morphological, syntactic, semantic, discourse, and pragmatic levels of language identical to those of spoken languages. To be sure, the results of this first revolution emanating from linguistic science have resoundingly demonstrated that the natural signed languages of deaf people around the world are real languages on formal linguistic grounds.

Revolution 2: Culture

A second revolution in thought began in the mid-1960s and 1970s. Here, both the scientific researchers studying natural signed languages and the Deaf people who used them began articulating the contours of Deaf culture.[5] Deaf people in different countries constitute a distinct cultural group of people among the majority culture. They have a natural language with which they live, work, and raise their children. Within Deaf culture there are Deaf traditions; customs; humor (including classic Deaf jokes); and art in vastly different formats, including stunning visual poetry, theater, literature, popular print-media venues (such as journals,

newspapers, and magazines), Internet venues (such as visual journals), cinema (including films by Deaf film directors), forms of dance and rhythmic expression common to music. To be sure, Deaf culture possesses all those features universal to being human. All of these features bind Deaf people into an authentic culture within the different countries of the world and, again, are precisely the dimensions that bind hearing people into many distinct cultures. As the revolution in understanding Deaf culture has been explored in numerous, readily accessible works, the focus of this chapter is on the third, and less well known, revolution in understanding the biological properties of linguistic processing and subsequent Deaf gains.[6]

Revolution 3: Biology

The third revolution began in the mid-1990s with the explosion of advanced neuroimaging technologies in combination with state-of-the-art behavioral methods, and continues through today. This particular revolution has brought about a most important advance in our understanding of the human mind, human language, and human signed languages. It involves the discovery from a wide array of disciplines within the neurosciences (especially the developmental cognitive neurosciences) that signed and spoken languages are *biologically equivalent*.

Scientific discoveries from my own lab of deaf and hearing researchers, for example, have found that signed and spoken languages are acquired by young deaf and hearing babies (respectively) in the same way and, crucially, on the same maturational timetable. That we observe an identical maturational time course shared across spoken and signed language acquisition is key. Despite radical modality differences between the hand and tongue—and despite the vast differences in home rearing, language, and cultural environment—human sign-exposed and speech-exposed children acquire language in similar ways. Such surprising similarities suggest that similar shared and biologically equivalent brain-based mechanisms underlie signed and spoken languages and contribute to the many complex factors that make possible human language acquisition. To be sure, early exposure to a signed language yields entirely normal development of human language acquisition. And this is dramatically so!

Young sign-exposed deaf babies produce manual babbling (yes, they babble on their hands!) at the identical developmental time when hearing babies produce vocal babbling (onset around six months). Deaf babies produce the same meaningless, rhythmically alternating (sign) phonetic and (sign) syllabic structures, and exhibit the same stages of babbling, over the first year of life.[7]

The human brain carves out onto the human hand the identical linguistic structures irrespective of modality differences (hands versus tongue). Interestingly, the babbling period is so central to early human language development that we also see it emerge in hearing babies in deaf homes who are exposed only to a signed language in early life. Here, they babble manually, though not vocally. We

also observe babbling in bilingual hearing babies who are exposed to sign and speech from birth and who produce, discretely, both manual and vocal babbling.

The remarkable discovery of manual babbling in young sign-exposed babies caught the scientific world's attention, because "babbling" was thought to be a universal milestone exclusive to human spoken-language acquisition that is fundamentally tied to (caused by) the development of the mouth and the hearing of sounds. It is not. Instead, the discovery of manual babbling was the first in a series of findings that would decouple human language from speech and suggest that the human brain must contain a finely honed sensitivity to *specific* underlying patterns at the heart of human language *structure*, rather than modality.[8]

Beyond babbling, when sign-exposed deaf babies (and hearing babies of deaf parents) reach the "first-word" milestone in sign language, the underlying concepts expressed in their early signs refer to the same things in the world as they do for a hearing child (irrespective of any ostensible sign "iconicity" at the lexical level). The young sign-exposed baby's development of semantic concepts and categories is also the same as a hearing child's. All children pass through the same early pragmatic, discourse, morphological, and syntactic developments irrespective of differences in language modality, language typology, and language topological structure.[9]

How can this be? At the time, such findings didn't make sense in light of the scientific discipline's looming theories involving the ostensibly biologically superior status of speech—specifically, that the maturation of speech perception and speech production mechanisms are the exclusive engine that drives early human language acquisition. If the brain's mechanisms for speech and sound development alone were driving a young hearing baby's language-acquisition milestones, how could it be that young deaf babies acquiring signed languages—languages without speech and sound—also achieved identical language milestones in sign and produced identical language structures (such as babbling), all on an identical timetable?

A new answer: in 2000, my team and I made the surprising discovery that key parts of human language structure were governed by the identical *brain tissue* across spoken and signed languages. Most noteworthy, this was true even for parts of human language structure that have been classically associated with sound and speech, such as phonology and phonological segmentation in language, and which, in turn, had been neuroanatomically linked to parts of the human brain assumed to be the lone bastion for the processing of sound for the past 125 years (specifically, the planum temporale [PT] in the superior temporal gyrus [STG]). Here we found that brain tissue and networks classically associated with speech and sound processing in hearing people also control sign-language processing for identical language functions.[10]

Our research had many intriguing findings, but, in particular, we found that

sign phonology is processed in the identical brain tissue as spoken phonology (PT/STG) even though signed languages have evolved in the absence of sound. Given the early behavioral-babbling and timing-milestone studies cited earlier, we were able to offer the hypothesis that the underlying "motor" driving spoken- and signed-language acquisition was biologically equivalent. Here, the new neuroimaging technology had permitted us to see that the brain tissue was indeed biologically identical!

Rather than being "set" for speech analysis, this STG tissue (previously assumed to be a unimodal sound-processing site that segments the linguistic stream into phonological units) is not exclusively sound-based at all. Instead, this tissue processes both the signed and speech linguistic streams and appears to be "set" for processing highly specific rhythmic-temporal alternating patterns (in maximal contrast) that lie at the core of all human-language phonological structure.

In addition to shared brain tissue underlying phonological processing for speech and sign, our team (and others) has discovered that all of the classic levels of language organization in spoken language (including phonology, morphology, syntax, and semantics) are processed in highly similar and overlapping brain tissue in deaf people processing signed languages.[11]

At our National Science Foundation, Science of Learning Center called Visual Language and Visual Learning, or VL2, in addition to observing that early sign exposure yields entirely normal language development, we have observed striking *advantages* to early-life exposure to a signed language. In the studies cited earlier, we observed select biologically equivalent brain structures underlying key parts of human signed- and spoken-language structure. In our center, we have observed that deaf children exposed to signed languages early in life demonstrate select advantages over age-matched hearing peers. This casts an entirely new light on the topic of Deaf Gain; here we have a biologically based Deaf Gain.

Biological development and early visual experience: Early exposure to a signed language in young deaf visual learners changes their visual processing and visual attention, a change that, in turn, has later "upstream" positive impact on higher cognition, language, and literacy, as well as on social-emotional self-regulation. Early-sign-exposed deaf infants attend to (and visually track) more robustly adult signers' faces and eye gaze, as compared to deaf and hearing infants with little or no exposure to signed language.[12] In turn, this permits the infant to learn vocabulary, meanings and reference (semantic relations), and language patterns rapidly. Studies of deaf toddlers reading books with their signing parents have found that these children's eye-gaze-tracking ability is indeed enhanced, resulting in increased early vocabulary, language, and literacy mastery, both in ASL and, most fascinating, in English.[13] And later in life, advantageous changes in visual processing are observed in deaf adult skilled readers, who show greatly increased reading eye span in English, as compared to hearing adult skilled readers.[14]

Biological development and early bilingual language experience: Early bilingual exposure to a natural signed language and a spoken language affords cognitive and, in a newly discovered finding, surprising language and reading advantages over age-matched monolingual children and adults. This holds for both deaf and hearing bilingual ASL/English children.[15] Notably, the studies reveal that early bilingual signed- and spoken-language exposure provides linguistic-processing strengths across both languages, and that access to a signed language *improves* a deaf child's performance in reading English. Moreover, early bilingual exposure affords the most robust and optimal lifelong cognitive and linguistic advantages over later dual- or second-language exposure.[16] Thus, old fears of language contamination and/or language delay when exposing a child to two languages early in life are scientifically unfounded. Similarly, old fears that early exposure to a signed language will hurt deaf children's acquisition of a spoken language are also scientifically unfounded, as instead we find powerful language and reading advantages in deaf children who are exposed early and bilingually to both signed and spoken language.

Biological development and the discovery of the role of visual phonology in learning to read English: Both neural and behavioral studies lay bare the brain's remarkable ability to develop alternative gateways to sound-based phonological decoding typical of, for example, an early English reader's use of sound phonological representations to access meaning from the printed word. There is now growing and very exciting evidence that young visual learners, deaf children, and adults also have—and use—a "visual phonological" level of language representation when accessing meaning from printed words in reading.[17] Here, the deaf reader is not using sound-based phonology but instead is using a visually based phonological level of language processing. This means that reading, which was once believed to require sound decoding in early reading to achieve reading mastery, need not require sound at all! What's in the deaf visual learner's brain regarding human language's "phonological" level of language organization appears to be, rather than sound phonological representations consisting of sound units, more akin to *visual* phonological representations consisting of *visual* units, including sensitivity to specific rhythmic-temporal patterning at the core of natural language structure, sign-phonetic and sign-syllabic units and their patterned movements, sign sentential prosodic patterning as well as visual finger spelling, and orthographic print patterns.[18]

That the human brain creates a visually based "phonological" level of language processing in the absence of sound is stunning in itself and reveals the centrality of this level of language organization in all human language processing. As we have seen, it also forces us to reconceptualize the nature of human language, as we see core levels of language organization being pushed out onto the hands and the tongue irrespective of language modality, and it decouples human language from speech.

Three Revolutions: Significance

Taken together, these three "quiet" revolutions can render a conceptual change in science and society. Yes, signed languages are "real" languages, and yes, deaf people have their own "real" culture, but the developmental and brain evidence does not support the "speech is superior" hypothesis. Instead, this new trilogy of evidence—the stunning identity of linguistic structure, culture, and biology across signed and spoken languages—has rendered a most remarkable revolution in thinking in our modern world regarding what human language is and what makes up being human. Speech and language have now been biologically decoupled. Speech is *not* language. "Language" resides in our brains and is distinct from its production. The *production* of language—be it either by the tongue or by the hands—is distinct from the *knowledge* of language. Knowledge of language is in our brains. The tongue is one means by which the brain can "out" human language—but not the only one. In early life, the human brain will take the hands if given the hands, or the tongue if given the tongue, and will treat them identically. In fact, the human brain does not discriminate between speech and sign but processes them identically, with *biological equivalence*. In light of this, it is indefensible to implement laws that deny Deaf individuals equal rights. How irregular it would be to have a human brain that does not discriminate between speech and sign, yet to live in a society that, flying in the face of human biological fact, makes laws that discriminate.

As a cognitive neuroscientist who has studied the biological foundations of human language for decades, I believe it is indefensible to implement public, medical, and educational practices that deny individuals who are deaf a basic human right—the right to early-life exposure to a natural human signed language. How can we do otherwise when decades of widespread scientific discoveries have demonstrated that signed languages are biologically equal in the human brain to the world's spoken languages? How can we do otherwise when science has demonstrated through powerful biological-developmental discoveries that early exposure to a signed language can provide cognitive and linguistic benefits in the developing signing deaf child? Especially fascinating, how can we do otherwise when we have consistently discovered that *all* children's early exposure to two languages—including a deaf child's early exposure to a signed and a spoken language, or a signing deaf child's exposure to English through print—affords remarkable, lifelong higher cognitive and linguistic benefits than monolingual exposure across the life span. How can we do otherwise when we have consistently discovered that early exposure to a signed language provides enhancements to the brain's visual-processing and visual-attention systems, which, in turn, provide benefits to the young deaf child's acquisition of vocabulary and language, as well as, most surprisingly, reading and literacy advantages? To be sure, how can we do otherwise when we have consistently observed the surprising: for example, that

early exposure to ASL provides reading advantages in English? Finally, how can we do otherwise when our science has consistently shown us that early exposure to a signed language affords advancements in the deaf child's social knowledge of the world, self-regulation, and, so important, the growing child's self-esteem?

We grow as human beings, as a culture, as a society, with new knowledge. We are enlightened. And the enlightenment that comes from new knowledge empowers us to change the world and make it a better place for all people. It is not new knowledge that is to be feared. Instead, the most profound damage we can do to ourselves and to others is to fail to see new knowledge before our eyes.

Notes

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