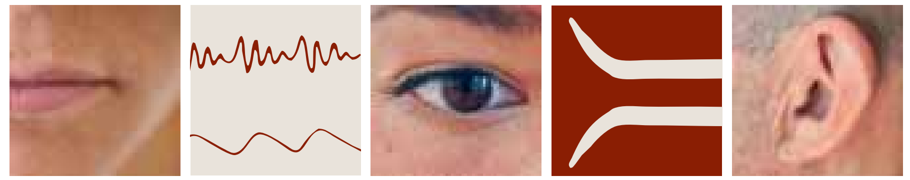
Haskins Laboratories



HASKINS LABORATORIES

THE SCIENCE OF THE SPOKEN AND WRITTEN WORD

Haskins Laboratories

MISSION STATEMENT

Haskins Laboratories is an independent, international, multidisciplinary community of researchers conducting basic research on spoken and written language. Exchanging ideas, fostering collaborations, and forging partnerships across the sciences, it produces groundbreaking research that enhances our understanding of—and reveals ways to improve or remediate—speech perception and production, reading and reading disabilities, and human communication.

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Talking and understanding what others say comes naturally to every healthy child. Children rapidly learn to speak and understand others, and can do so with no formal training. Literacy is a very different matter. Many individuals as well as entire societies do not read or write. Although most people take language for granted, understanding the nature of speech and its relationship to literacy is anything but simple. How do we acquire, produce, and understand speech, which is our birthright by biological evolution? How do we achieve literacy, which is a cultural artifact? What bridges these dual domains of language? Exploring such questions opens a window on the inner workings of the mind.

Answering these fascinating questions is of more than scientific interest to those who cannot take language for granted.

Disorders, disease, and trauma impair some people’s ability to speak and/or understand the speech of others. Disabilities and inadequate education prevent many more from learning to read and write. The science of the spoken and the written word promises to help these people participate more fully in their humanity and our society.

The characters that appear above and throughout this book are drawn from the phonetic alphabet and various written languages' alphabets.

Haskins Laboratories has been at the forefront of this research for seventy years. It is the nation’s leading independent, multidisciplinary community of scientists studying speech, language, and reading. Its theoretical and technological breakthroughs are continually advancing the science of the spoken and the written word, and the practical applications of its discoveries are improving human communication.

SPEECH, SCRIPT, AND COMMUNICATION: A PRIMER

Birds, bees, and even poorly educated fleas communicate with each other by song, flight-dance, or the twitch of antennae, but only humans possess the gift and the power of language. Speaking comes almost as naturally to us as breathing. Indeed, that's in part what it is: modulating the air we exhale from our lungs with our larynx, palate, jaw, tongue, and lips to form vowels and consonants. Speech is so integral to our identity that it may have emerged simultaneously with the origin of *Homo sapiens* some 200,000 years ago or even earlier, when an upright ancestor emitted a sound more potentially meaningful than a chimpanzee's grunt.

Healthy infants typically start babbling at six to eight months and begin to utter words at twelve to fifteen months, sentences a few months later. In a child's third year, these sentences become fluent. Six-year-olds know an average of 13,000 words. By the time we graduate from high school, our vocabularies have burgeoned to approximately 60,000 words.

As inevitably as we acquire our native language, we lose the capacity to master another one easily. By the age of ten to twelve months, infants' ability to distinguish some sounds that are not salient in the language spoken around them begins to diminish. A Japanese baby, for instance, no longer registers the difference between English's "l"s and "r"s. By puberty, our brains have lost the plasticity that would enable us to speak a foreign language without a telltale accent.

Where in the cerebral cortex is our language facility concentrated? A critical region for language is clustered around the Sylvian fissure in the left hemisphere of most people's brains (including those of a majority of left-handed people), which is why most of us perceive speech a few milliseconds earlier and more accurately through our right ear (which is connected to the left hemisphere), while many people hear music more acutely through their left ear.

Functional Magnetic Resonance Imaging (fMRI) usually reveals a flush of activity in the left hemisphere when people read or converse. One of the fascinations of speech for many scientists (and non-scientists as well) is that it opens a window on what goes on inside our heads.

“Personally,” wrote Noam Chomsky, the father of modern linguistics, “I am primarily intrigued by the possibility of learning something, from the study of language, that will bring to light inherent properties of the human mind.”

The basic building blocks of speech are phonemes. The ”b,” short “a,” and “g” that form the word “bag,” for example, are phonemes. A change in a phoneme can create a meaning change (“rag,” “bog,” “bat”). English consists of about four dozen such phonemes. In contrast, the American Indian language Mura has 11 phonemes. The click language XuÚ! has 141.

It has proven very difficult to reduce phonemes to acoustic properties, as evidenced by the difficulty that computer scientists have experienced in creating useful speech recognition systems. Moreover, there is evidence that phonemes consist of more than sounds. If you listen through headphones to a voice saying “ba” as you watch a video of a face saying “da,” the visual information trumps the acoustic information and you hear “da.” This phenomenon is called the “McGurk effect” after one of its discoverers, Harry McGurk.

Words are even more confounding than the syllables that compose them. Harvard psychologist and bestselling author Steven Pinker writes, “In the speech sound wave, one word runs into the next seamlessly; there are no little silences between spoken words the way there are white spaces between written words.”

Research conducted at Haskins Laboratories over seventy years has convinced scientists in many disciplines to consider the sounds and words that constitute speech not as discrete, disembodied acoustical entities but, rather, as physical events or gestures, the overlapping actions of our larynx, palate, tongue, jaw, and lips. Speech is a complex neurological and physiological system. Understanding the system of speech can help us synthesize, recognize, and improve it.

Writing makes speech visible. Although it is based on the spoken word, it consists of symbols rather than actions. Many of these symbols originated in pictographs. Turn the letter “A” upside down and you can still make out an ox head; it takes a little more imagination to discern the tent flap in a “D.” But the letters in written languages became symbols of sounds: phonemes in English and Finnish, entire syllables in Mayan and Japanese, a combination of both in Korean.

The written word appeared much later than the spoken word. The earliest known script, the cuneiform that the Sumerians incised on clay tablets, is only 4,000 to 5,000 years old. Borrowing characters from the Phoenicians, the ancient Greeks created the first fully alphabetic system of writing, memorialized in the very word, “alphabet” (alpha, beta…).

The relatively recent invention of written languages and the abundance of non-literate societies and individuals indicate that reading is not a biological, evolutionary imperative, like speech, but a cultural acquisition. We don’t go to school to learn to talk, but some kind of education is necessary to grasp that the letters in our alphabet approximate phonemes and that b-a-g spells “bag.” Some people do not learn this lesson easily because they suffer from dyslexia or other learning disabilities, poor teaching, or both.

At Haskins Laboratories, psychology, physiology, linguistics, neuroscience, cognitive science, and computer science are illuminating the connections (and disconnections) between the spoken and the written word.

Carol A. Fowler

Sophisticated behavioral research, imaging technologies that peer inside the brain, and computer models that simulate mental and physiological activities are enabling researchers to make spectacular advances in the science of the spoken and the written word. Haskins Laboratories is on the forefront of this exciting field, deepening our understanding of humanity and civilization and helping people to participate more fully in both.

ON THE FOREFRONT OF AN EXCITING FIELD

As Haskins Laboratories enters its eighth decade, Dr. Carol A. Fowler is proud that its research is more robust and timely than ever. “We’re making significant strides in understanding how people use language to co-operate and get things done in the world,” says the private, non-profit laboratory’s President and Director of Research.

Dr. Louis Goldstein, a Senior Scientist at Haskins, shares her conviction: “We have, or are close to having, the tools we need to explore the fundamental nature of language forms in speech and print: functional MRI, ultrasound, magnetometers, eye-trackers, and dynamic mathematical and computer models of motion, change, and networks.”

Dr. Goldstein, Chairman of Yale University’s Linguistics Department, and Dr. Fowler, a Professor of Psychology at the University of Connecticut and Adjunct Professor of Psychology and Linguistics at Yale, represent the two universities with which Haskins Laboratories has been affiliated since 1970. Most Haskins researchers hold dual appointments at these or other universities. Such arrangements insure the Laboratories against insularity by continually exposing Haskins researchers to the new and different ideas of fellow faculty members, and provide the scientists with eager students.

“You want to have students, because they’re the people who are going to make the next generation of discoveries,” Dr. Goldstein says. Independence, he explains, gives Haskins “more informality, flexibility, and camaraderie.” That independence and decades of dedicated research have made Haskins Laboratories, in the words of Steven Pinker, “Speech Central.” (A chronological account of discoveries made at Haskins Laboratories appears on pages 38-41.)

One research area of particular interest to Dr. Goldstein is slips of the tongue. While many psychologists have speculated about what goes on inside a person’s head when he or she makes a vocal slip and says “poffee cot,” for example, instead of “coffee pot,” Dr. Goldstein has studied what goes on in the vocal tract when such slips occur. In addition to shedding light on the dynamics of speech production, his investigations, he hopes, will benefit people with hearing disorders, aphasia, and other impairments by “providing key information about what speech actually is and helping them to speak more comprehensibly. We will understand a lot more about ourselves, and about how to deal with people whose communications are disordered.”

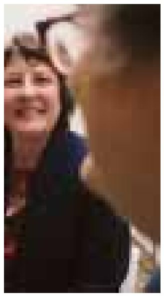
Dr. Fowler is especially interested in the ways imitation and interaction influence communication. “Language is something that happens between people,” she says. “When they talk to each other their dialects and intonations begin to converge as they try literally to get on the same wavelength.” We often mirror each other’s gestures as well, crossing our legs after the person we’re speaking with does, for instance, or swaying in sync.

Dr. Fowler has shown that this “postural sway,” measured by sensors attached to experimental subjects’ hips, can occur during a cooperative conversation even when participants cannot see each other. Now she is designing experiments to discern what happens when people are speaking under competitive rather than cooperative circumstances. She is also using functional MRI to trace neuronal activity when people hear a word, see it being spoken, say it to themselves, or silently mouth it.

Both scientists are united in believing that language is a dynamic, public phenomenon. “To turn what Chomsky said on its head,” Dr. Goldstein explains, “language is more like an organism than an organ.” Dr. Fowler elaborates: “The forms a language assumes come partly from ourselves, but also from our interactions with other speakers. That’s one reason why it’s continually changing. Teenagers want to sound like each other, not their parents. Bill Clinton talked about ‘growing’ the economy, and suddenly everyone was using the verb in a way they never had before.”

Thanks to research conducted at, and inspired by, Haskins Laboratories, people are understanding the spoken and written word in ways they never did before. “The research here is revolutionary,” says Dr. Goldstein.

“This is where it all began,” says Dr. Fowler. And where it continues.



Louis Goldstein

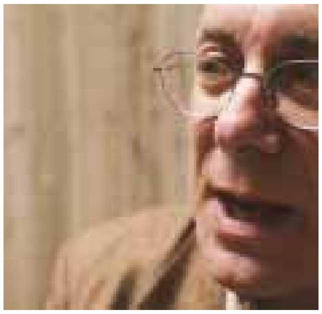
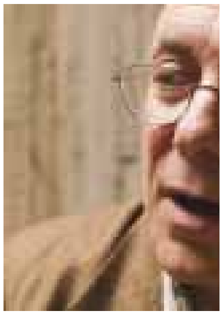
‘The research here is revolutionary.’

A RECORD OF THEORETICAL AND TECHNOLOGICAL INNOVATION

Haskins Laboratories has a long history of technological and theoretical innovation, from creating the first prototype of a reading machine for the blind to developing the landmark concept of phonemic awareness as a critical preparation for learning to read. Its record of achievement, past and present, is compelling evidence that it will continue to conduct cutting-edge research in the future.

Catherine T. Best

Philip E. Rubin



‘You can’t predict the future, but you can bet on it. And Haskins has a long track record of scientific achievement.’

Although basic research is at the heart of Haskins Laboratories' mission, the project that launched its investigations of the spoken and written word was practical and applied. During World War II, Haskins researchers Drs. Franklin S. Cooper and Alvin M. Liberman began work on a reading machine for blinded veterans that translated printed text into audible signals. Their first attempts linked a unique sound to each letter and failed dismally. This convinced them that speech is uniquely able to convey language, and that they had to acquire a deeper knowledge of speech in order to develop a successful reading machine. Their investigations and those of their colleague, Dr. Ignatius G. Mattingly, eventually resulted in a prototype that converted typescript into synthetic speech and "read" a "Dear Abby" newspaper column to residents of a Veterans Administration Blind Rehabilitation Center.

This research also led to a revolutionary new theoretical and empirical understanding of speech as a motor or gestural activity, as well as to a new approach to teaching reading.

"Adding to our basic knowledge is absolutely essential to technological progress and improvements in the clinical realm," says Dr. Philip E. Rubin. "You can't know at the outset what the commercial or clinical applications of your research will be, but ultimately it will be applied."

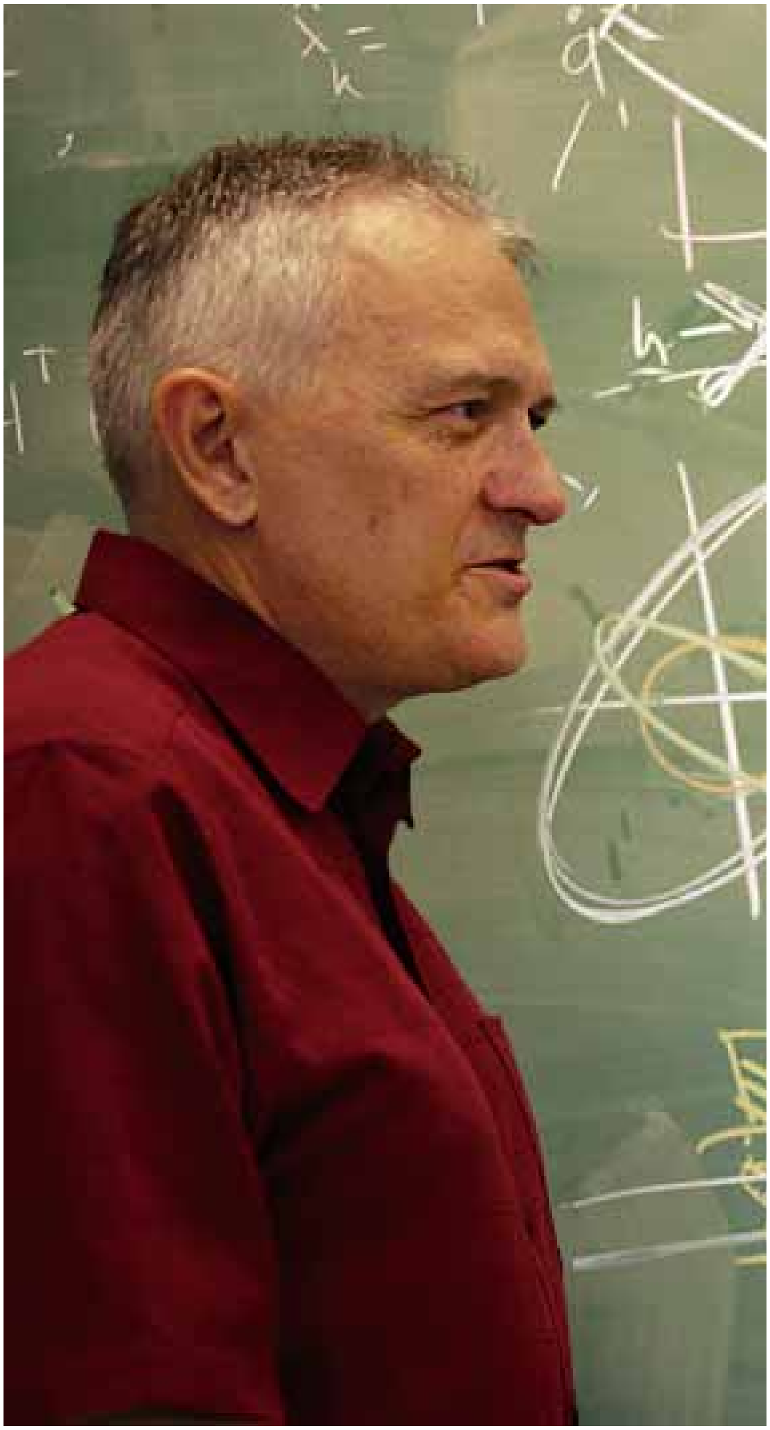
After three "very hectic and very rewarding" years spent directing the National Science Foundation's Division of Behavioral and Cognitive Sciences, Dr. Rubin recently returned to Haskins to become its CEO and Vice President. He is also a research affiliate of Yale's Psychology Department and an adjunct professor in the Department of Surgery, Otolaryngology, at the Yale University School of Medicine.

What originally attracted Dr. Rubin to Haskins Laboratories was its unusual combination of theoretical inquiry and technological innovation. He himself has added to those innovations over the years by developing, with Dr. Paul Mermelstein, and other colleagues, the first articulatory synthesizer that could be used as an interactive tool for testing the relationship between the production and perception of speech ("Think of speech as a ballet," he explains, "and of this as a tool to orchestrate it over time."), and by creating the sinewave synthesizer. Dr. Rubin, a former rock and roll guitarist, used frequencies derived from human speech to drive a music synthesizer he had created and came up with a new way to test how people perceive and differentiate speech.

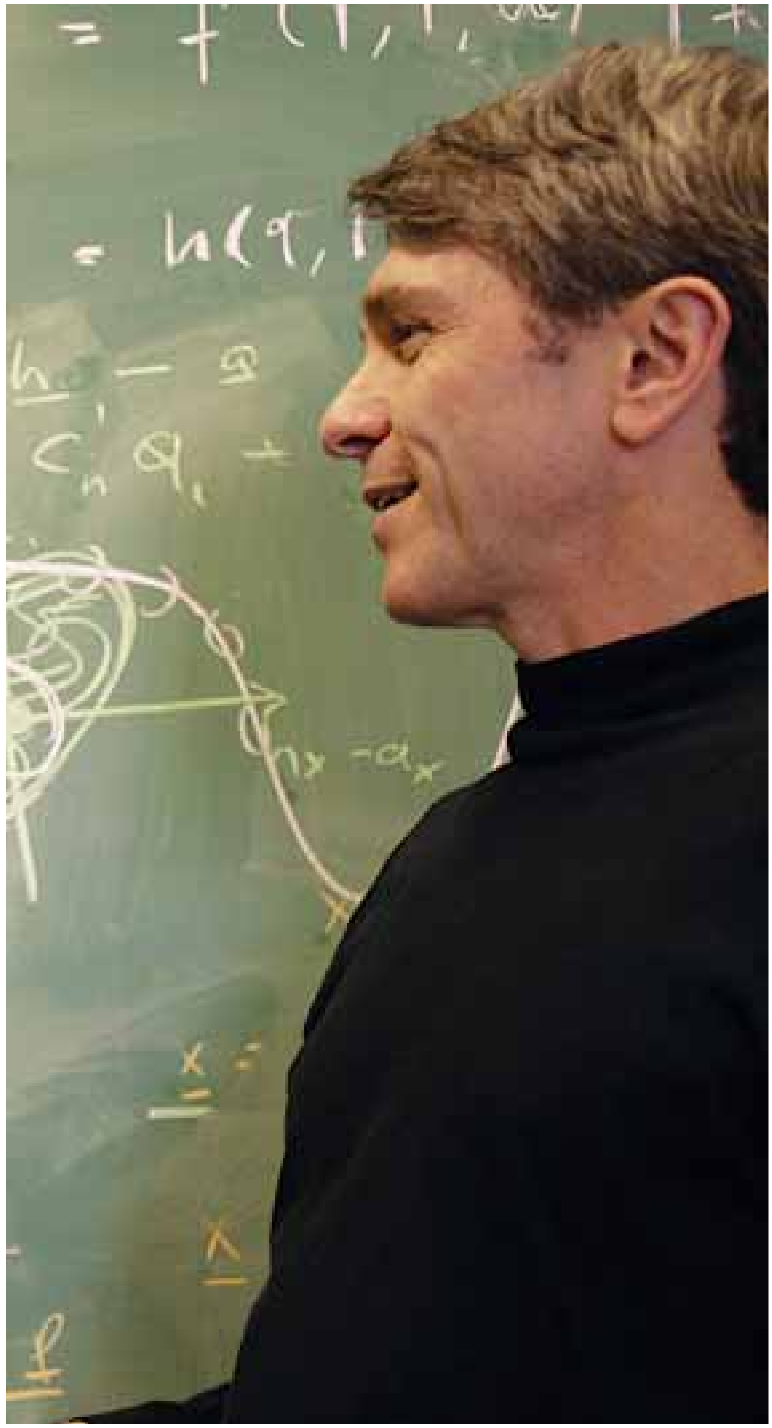
Dr. Catherine T. Best, a Haskins Senior Scientist who recently left Wesleyan University to become a Chair in Psycholinguistic Research at the University of Western Sydney's MARCS Auditory Laboratories in Australia, has used both the articulatory synthesizer and the sinewave synthesizer in her own research. When she was working on her doctorate at Michigan State University, studying the responses of infants to the sounds of speech, she made several trips to New Haven, often driving all night, because Haskins was one of the only facilities with the computers and speech synthesizers her experiments required. "Most of the tools we have today for manipulating natural speech are derived from a foundation that was laid down here," she says.

Among other subjects, Dr. Best studies how our experience of our own language affects our perception of other languages, from Japanese to the clicks of Zulu. Her research may prove pertinent in today's global economy when instantaneous communications and increased immigration expose many people to more languages.

"You can't predict the future," Dr. Rubin says, "but you can bet on it. And Haskins has a long track record of scientific achievement."



Vincent Gracco



David J. Ostry

INDEPENDENT AND INTERDISCIPLINARY

Haskins Laboratories enjoys a distinct advantage as an independent research center. Crossing the boundaries of universities as well as disciplines, it has created a critical mass of full-time, part-time, and visiting psychologists, linguists, neuroscientists, physicists, engineers, and other specialists who share information and insights and frequently collaborate as they study important problems such as speech perception and production, reading, and dyslexia that are too complex for research conducted from a single perspective ever to resolve.

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Drs. David J. Ostry and Vincent Gracco are colleagues at Haskins Laboratories and McGill University, but there the resemblance ends. Dr. Ostry is an engineer and neuro-physiologist who studies the role of "somatosensory input" in human speech and movement. Such feedback from nerve cells, for instance, enables many people who become deaf as adults to continue to talk intelligibly for many years. Dr. Gracco is a speech pathologist with a particular interest in stuttering. Their differences exemplify the interdisciplinary nature of Haskins research.

Indeed, Dr. Gracco says it was "the inherent interdisciplinarity of speech pathology" that attracted him to the field and then to Haskins Laboratories. "Speech is such a complicated process," he explains. "To understand what exactly is going wrong in a patient, you have to know something about the nervous system, about physiology, about behavior, about language, even mathematics, statistics, engineering, and medical subspecialties."

"By making room for everyone in the same building, Haskins gets a lot of things done," adds Dr. Ostry. "There's a remarkable concentration of people here." This concentration presents unusual opportunities for collaboration. With Haskins Vice President of Research Dr. Douglas H. Whalen, for instance, Dr. Ostry has used ultrasound to measure tongue movement. "It's a kind of project I could only have done at Haskins." Another device that he employs at the Laboratories applies pressure to the lower jaw in a manner that modifies somatosensory feedback while having minimal audible effect. Dr. Ostry's experiments hold promise for helping the hearing- and speech-impaired speak more clearly and effectively.

Dr. Gracco is using functional MRI and other imaging technologies to study the brain anatomy and activity of stutterers. "There's something different about the way they use their brains," he says. "The anatomical differences in the brain are consistent with functional differences." Studies suggest there is a genetic link or predisposition to stuttering, and there tends to be more speech activity in the right hemisphere of a stutterer's brain than in those of most non-stutterers. Treatment tends to shift activity toward the left hemisphere, but no therapy is more than 75 percent successful, according to Dr. Gracco, who wants to use imaging technology to test the efficacy of cures.

Marveling at the large number of scientists who work at Haskins during the course of a year, more than fifty of them senior researchers, Dr. Gracco says, "It's impossible to find another place that has such a critical mass."

‘By making room for everyone in the same building, Haskins gets a lot of things done. There’s a remarkable concentration of people here.’

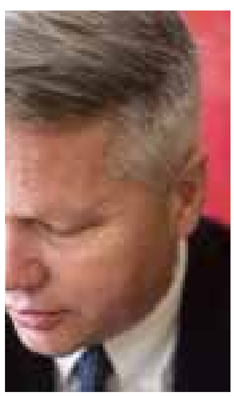


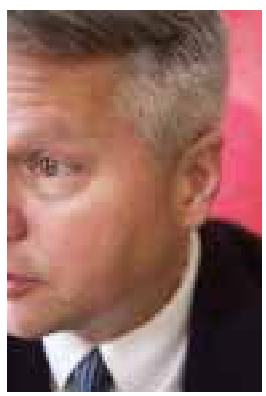

INTEGRITY AND OBJECTIVITY

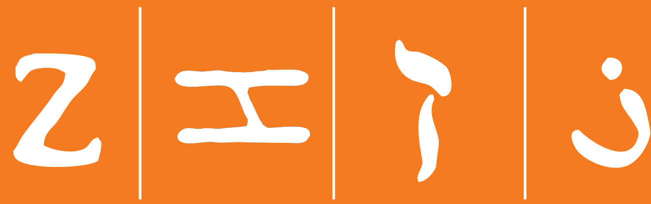
Haskins Laboratories is dedicated to basic research and hard science, from developing the first interactive software replicating the interplay of the tongue, lips, jaw, and palate in human speech to using functional Magnetic Resonance Imaging to study blood flows in the brain as a child reads. This grounding in objective research, which Haskins scientists pursue wherever it leads, gives the work of the Laboratories special credibility at a time when controversy surrounds many issues concerning language and reading.

Kenneth R. Pugh

‘I can’t say enough about the Haskins Labs’ scientific integrity,’ says an official at the National Institute of Child Health and Human Development, calling Haskins ‘a national treasure.’







When Dr. Alvin Liberman headed Haskins Laboratories during the 1970s and '80s, he would ask researchers daily, "Made any discoveries today?" "And you'd damned well better have an answer," recalls Senior Scientist Dr. Kenneth R. Pugh, a psychologist who is also a Research Scientist in the Department of Pediatrics at Yale University School of Medicine.

Scientific zeal, accompanied by equally scientific scrupulousness, still prevails at the Laboratories. "There is a fundamental empiricism at Haskins," says Dr. Pugh, "a willingness to be led by the data, and an absolute joy in pursuing the truth for its own sake. The diversity of opinions and disciplines here create checks and balances."

Dr. G. Reid Lyon, Chief of the Child Development and Human Behavior Branch of the National Institute of Child Health and Human Development (NICHD), agrees. "I can't say enough about the Haskins Labs' scientific integrity," says Dr. Lyon, who relied heavily on Haskins's reading research to win White House support for science-based educational methods and calls Haskins "a national treasure." Although education is frequently a political and cultural battleground, Dr. Lyon says, "Science should be above the fray."

Determined to ground the study of the human mind in neurobiology, Dr. Pugh designed a battery of experiments and measures for using functional MRI to study brain activity in people with reading disabilities. "It was a very heady time and extremely high-risk," he says, "because we didn't know if we would be able to measure anything meaningful." This pioneering work has been highly influential and widely adopted, yet Dr. Pugh cautions, "We're still in kindergarten when it comes to understanding the functions of different areas of the brain, even though I map it endlessly."

Now Dr. Pugh, with Haskins colleagues Drs. Hollis S. Scarborough and Rebecca Sandak, is undertaking a groundbreaking collaboration with the Kennedy Krieger Institute, a Baltimore-based research, clinical, and educational facility for children and young adults with neurological disorders and developmental disabilities, and with the Educational Testing Service. They are pooling resources and expertise to assess three different approaches to treating adolescent reading disabilities, using functional MRI, behavioral testing, and computer analysis to monitor students' progress. Dr. Pugh is especially excited by the project because little research has been conducted in adolescent reading disabilities. "People seldom teach reading to 12-to-17-year-olds, and they're falling through the cracks."

Kennedy Krieger President and CEO Dr. Gary W. Goldstein calls the study, which is funded by the National Institutes of Health and the Department of Education, "a natural collaboration, and a very productive learning experience for us all. We're bridging the gap between educational research and neuroscience. After all, that's what teachers do: they rearrange people's minds. Education is applied neuroscience."

Douglas H. Whalen

The basic research of Haskins Laboratories continually yields practical applications that enhance the quality of our lives. Work currently underway at the Laboratories may contribute to earlier medical diagnoses, for example, to more effective treatment of stuttering, to new methods of teaching and learning a second language, and to the creation of more reliable voice-recognition systems for security and other purposes.

ENHANCING THE QUALITY OF OUR LIVES

Dr. Douglas H. Whalen is ideally suited for his job. “I’m restless,” says the Vice President of Research at Haskins Laboratories. “I’m interested in everything that goes on here.” His primary area of concentration is basic research in the perception and production of speech, which is fraught with implications for and applications in everyday life. “What seems like a very technical, theoretical debate has real-world significance,” he explains, noting that his investigations may lead to fine-tuning the frequencies of cochlear implants or improving speech-recognition technology. Today’s speech-recognition systems, Dr. Whalen observes, suffer from “the curse of the 90 percent.” Mistaking one word out of ten can impede communication rather than enhance it, he says, and “it’s taken them forever to become only 90 percent accurate.”

Dr. Whalen and Haskins Senior Scientist Dr. Khalil Iskarous were using ultrasound to study the movement of the tongue when a colleague, Dr. Carol Gracco, made a serendipitous suggestion exemplifying the creative collaborations Haskins fosters. The speech pathologist set them thinking about Parkinson’s disease. “The tongue is all muscle,” Dr. Whalen says, “and more like an octopus’s tentacle than any other human muscle.” Parkinson’s is characterized by muscular rigidity. Would ultrasound reveal anything about its effect on the tongue? “It was amazingly clear,” Dr. Whalen says. “People with Parkinson’s look as if they were shoving a ball around their mouth even if you can’t hear the difference.” Their findings are extremely preliminary, but Dr. Whalen hopes that ultrasound may prove a useful diagnostic tool, and that the efficacy of various treatments of Parkinson’s might be gauged by the extent to which they literally loosen a patient’s tongue.

In another collaboration, Dr. Whalen and Haskins Research Affiliate Dr. Julia R. Irwin began examining gender differences in people’s responses to the McGurk effect. Women are more prone than men to hear what they see, registering the silent syllable formed by lips on film even when it differs from the syllable that is audible through headphones. Autism is more prevalent among males, and Dr. Whalen and Dr. Irwin’s experiments have yielded some evidence that autistic children, who tend not to look at speakers’ faces, do not display the McGurk effect. Now they hope to study whether such insusceptibility might provide an early diagnosis of autism. Somehow Dr. Whalen has also found the time to establish and oversee the Endangered Language Fund, which dispenses grants for community-based research projects to record and preserve native languages. Today, Dr. Whalen points out, thanks to the field recordings of earlier generations of linguists, many languages can be considered dormant rather than dead. Three to four hundred Native American languages were once spoken in California, for example, and the descendants of some tribes are trying to revive them on the basis of field recordings. From Oklahoma, where Dr. Whalen grew up and has sponsored work on a Cheyenne-Arapaho reservation, to western Siberia, where researchers have recorded the last surviving epic singer in the little-known language of Shor, the Endangered Language Fund, like Haskins Laboratories, is active worldwide.

‘What seems like a very technical, theoretical debate has real-world significance.’

Susan A. Brady

In 2000, Dr. Susan A. Brady and another Haskins colleague, the late Dr. Anne Fowler, launched the Haskins Early Reading Success (ERS) Initiative, a professional development program for elementary teachers in low-performing schools funded by the U.S. Department of Education. Dr. Brady, a Professor of Psychology at the University of Rhode Island, felt frustrated that the knowledge about reading that researchers at Haskins Laboratories and elsewhere had painstakingly accumulated over decades was not getting into the hands and heads of teachers. “There’s a chasm between the research world and the educational world,” Dr. Brady says, “that we must bridge.”

TEACHING READING IS ROCKET SCIENCE

One of her mentors at Haskins, the late Dr. Isabelle Liberman, "cared passionately about reading instruction and remediation," Dr. Brady explains. "She wanted research to impinge on practice. In turn, I have long felt a dual responsibility to conduct research on reading and to see that insights from research reach the classroom." For Dr. Brady there was also a "personal hook." Her younger brother, who eventually became an engineer without attending college, is dyslexic. "I watched him have a difficult time in school learning to read, and spelling is still a challenge."

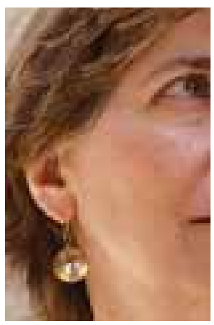
Early Reading Success helped teachers develop students' ability to recognize that spoken words consist of phonemic segments and to identify the phonemes in spoken words and syllables. Such phoneme awareness is necessary for understanding what the letters in the alphabet stand for and is an essential component of preparation for learning to read. In its very first year, Early Reading Success raised from 30 to 50 percent the proportion of children in participating schools who entered first grade meeting the benchmark for requisite early reading skills. "One of the things we have to overcome is low expectations for poor children," Dr. Brady says. "Another is the belief that kindergarten should not have academic goals; it is critical to give students the foundation they need for learning to read."

The concept of phoneme awareness, pioneered at Haskins, is a major contribution to education. Dr. Reid Lyon at the National Institute of Child Health and Human Development calls the discovery of phoneme awareness "a national and even international accomplishment that has literally saved children's lives."

The Haskins reading program is educating the scientists involved as well as teachers and schoolchildren. "Working with our team of mentors in the schools, our understanding of what teaching reading requires keeps growing," says Dr. Brady, who believes it is more complex than most advocates of whole language instruction on the one hand or of traditional phonics on the other hand realize. "Our approach entails phoneme awareness, phonics, fluency, vocabulary development, and comprehension. Teaching reading is rocket science," she says, quoting a colleague, Dr. Louisa Moats. "Every year I'm learning more about reading development and teaching reading. This shapes research questions. The cross-talk between research and teaching benefits both sides."

Building on ERS, Dr. Brady, together with Dr. Margie Gillis, has undertaken a larger project, Mastering Reading Instruction. Funded by the U.S. Department of Education's Institute of Education Science, they are carefully comparing methods of professional development to determine the key elements for training first-grade teachers to be expert at teaching children to read. "Given the low reading achievement of more than a third of the elementary students in the U.S.," Dr. Brady says, "it is crucial to determine how to give teachers the knowledge and skills they need to help all children learn to read adequately."

The discovery of phoneme awareness is ‘a national and even international accomplishment that has literally saved children’s lives.’



The reach of Haskins Laboratories is global. Its scientists are affiliated with universities and research institutions throughout the world, and it trains postdoctoral fellows from many countries. Together the Laboratories' researchers and alumni are advancing the science of the spoken and the written word internationally.

INTERNATIONAL IMPACT

Ram Frost

‘Haskins has an enormous amount of intellectual credit abroad. For me, coming here is wonderful because I think it’s the best lab in the world.’

"I make my pilgrimage to Haskins at least twice a year," says Dr. Ram Frost, who comes all the way from Jerusalem, where he is a Professor of Psychology at Hebrew University and heads the Laboratory for Verbal Information Processing.

As a postdoctoral fellow at Haskins Laboratories, the Israeli scientist conducted landmark research in how the disparate writing systems of English, Hebrew, and Serbo-Croatian affect the way people read and write. His findings suggested that reading English, whose letters represent phonemes, Hebrew, whose letters typically represent syllables but seldom specify vowels, and Serbo-Croatian, which is highly unusual because many speakers use both the Cyrillic and Roman alphabets, requires different cognitive strategies and therefore different instructional methods.
Now Dr. Frost is extending his investigations to Arabic, as well.

Dr. Frost considers his laboratory "an auxiliary lab of Haskins in some senses," and it facilitates Haskins scientists' research in Semitic languages such as Hebrew and Arabic. "Haskins people travel to other labs around the world to do research," he says. "The exchange is bidirectional, and this multinational web is unique to Haskins."

Don't just take Dr. Frost's word for this. Gordon Ramsay, a British electronic engineer and computer scientist, came to Haskins as a Research Associate after working at l'Institut de la Communication Parlée in Grenoble, France. "There's a constant flow of people coming through Haskins," says Ramsay, "and they travel enormous distances to come here. People don't do that at other labs. Haskins has an enormous amount of intellectual credit abroad. For me, coming here is wonderful because I think it's the best lab in the world."

Dr. Frost's work is a prime example of Haskins's international impact. Deploring the "total chaos in reading results" in Israeli schools, he fought "a lonely fight" against the Ministry of Education that he eventually won. Parliament formed a committee on which he served, and subsequently he headed a task force that revised all the materials for reading instructions in primary schools. "In two years the entire system of teaching reading in Israel has changed," he says. "I managed to import to Israel the revolution we saw in America." In this revolution as in so much else, Haskins Laboratories has played an influential role.

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DECADES OF DISCOVERY

Scores of researchers have contributed to scientific breakthroughs at Haskins Laboratories over the past seventy years. All of them are indebted to the pioneering work and inspiring leadership of Caryl P. Haskins, Franklin S. Cooper, and Alvin M. Liberman.

1930s

Caryl Haskins and Franklin Cooper establish Haskins Laboratories in 1935. Affiliated with Harvard University, MIT, and Union College in Schenectady, NY, Haskins conducts research in microbiology, radiation physics, and other fields in Cambridge, MA and Schenectady.

In 1939 the Laboratories moves its center to New York City. Seymour Hutner joins the staff to set up a research program in microbiology, genetics, and nutrition. The descendant of this program is now part of Pace University in New York City.

1940s

The U.S. Office of Scientific Research and Development, under Vannevar Bush, asks Haskins Laboratories to evaluate and develop technologies for assisting blinded World War II veterans.

Experimental psychologist Alvin Liberman joins the Laboratories to assist in developing a "sound alphabet," an auditory Braille, as it were, to represent the letters in a text for use in a reading machine for the blind. Cooper and Liberman find, however, that because the ear's ability to resolve a rapid sequence of discrete sounds into its components is limited, no acoustic code they devise can convey text at more than one-tenth the typical rate of speech. Guiding research questions now become: Why is speech so much more effective than other acoustic signals? How do we speak so fast? How does speech evade limits on the temporal resolving power of the ear? How is reading related to speech perception? And, more generally, is there some special, perhaps biologically ordained, relation between speech and the structure of language?

The conclusions of this and other research at the Laboratories appear in *Blindness: Modern Approaches to the Unseen Environment*, edited by co-investigator Paul Zahl. This influential book, published in 1950, identifies scientific and technical obstacles that must be overcome to develop practical devices to assist blind mobility and reading.

Luigi Provasoli joins the Laboratories to set up a research program in marine biology. The program moves to Yale University in 1970 and disbands with Provasoli's retirement in 1978.

1950s

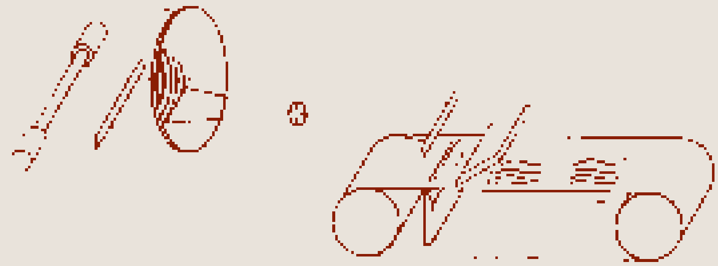
Cooper invents the Pattern Playback, a machine that converts pictures of the acoustic patterns of speech back into sound. With this device Liberman, Cooper, and Pierre Delattre (later joined by Katherine Safford Harris, Leigh Lisker, and others) discover acoustic cues for perception of phonetic segments (consonants and vowels). They find that segments are not usually isolated bits in the speech stream, and that cues vary widely with context due to coarticulation, that is, to the overlapping actions of larynx, soft palate, tongue, jaw, and lips within and across syllables. Liberman, Cooper, and Delattre conclude that the perception of phonetic segments is more simply related to articulation than to acoustic signals. They propose a "motor theory" of speech perception to resolve the acoustic complexity: we perceive speech, they hypothesize, by learned associations between speech sounds and sensory feedback from their articulation.

Liberman, Harris, and colleagues, working with synthetic speech, discover that listeners discriminate a given acoustic difference between consonants that belong in different categories more easily than they discriminate the same difference between consonants in the same category. Dubbed "categorical perception" and initially believed peculiar to speech, the phenomenon inspires years of research by Peter Eimas, Michael Studdert-Kennedy, David Pisoni, and others at Haskins and elsewhere. Today, though categorical perception is no longer seen as peculiar to speech, its experimental paradigm retains utility as a measure of phonological skills in young children.

Liberman, aided by Frances Ingemann and others, organizes the results of the work on cues into a groundbreaking set of rules for speech synthesis by the Pattern Playback.

1960s

Cooper and Harris, working with Peter MacNeilage, are the first researchers in the U.S. to use electromyographic techniques, pioneered at the University of Tokyo, to study the neuromuscular organization of speech. They discover that relations between muscle actions and phonetic segments are no simpler or more transparent than relations between acoustic



A schematic rendering of the Pattern Playback machine, which converts pictures of the acoustic patterns of speech back into sound

signals and phonetic segments.

Lisker and Arthur Abramson look for simplification at the level of articulatory action in the voicing of certain contrasting consonants (/b/, /d/, /g/ vs. /p/, /t/, /k/). They show by acoustic measurements in eleven languages and by cross-language perceptual studies with synthetic speech that many acoustic properties of voicing contrasts arise from variations in voice onset time, that is, in the relative phasing of the onset of vocal cord vibration and the end of a consonant. Their work is widely replicated and elaborated, here and abroad, over following decades.

Donald Shankweiler and Studdert-Kennedy introduce dichotic listening into speech research, presenting different nonsense syllables simultaneously to opposite ears. They demonstrate dissociation of phonetic (speech) and auditory (nonspeech) perception by finding that phonetic structure devoid of meaning is an integral part of language, typically processed in the left cerebral hemisphere. Their work is replicated and developed in many laboratories over following years.

Alvin Liberman, Cooper, Shankweiler, and Studdert-Kennedy summarize and interpret fifteen years of research in "Perception of the Speech Code," still among the most cited papers in the speech literature. It sets the agenda for many years of research at Haskins and elsewhere by describing speech as a code in which speakers overlap (or coarticulate) segments to form syllables. These units last long enough to be resolved by the ear of a listener, who recovers segments from syllables by means of a specialized decoder in the brain's left hemisphere that is formed from overlapping input and output neural networks—a physiologically grounded "motor theory."

Haskins acquires its first computer and connects it to a speech synthesizer designed and built by the Laboratories' engineers. Ignatius Mattingly, with British collaborators John N. Holmes and J. N. Shearme, adapts the Pattern Playback rules to write the first computer program for synthesizing continuous speech from a phonetically spelled input. A further step toward a reading machine for the blind combines Mattingly's program with an automatic look-up procedure for converting alphabetic text into strings of phonetic symbols.

1970s

Haskins Laboratories completes the move to New Haven, CT, begun in 1969, and enters into affiliation agreements with Yale University and the University of Connecticut.

Recognizing the Laboratories' unique facilities for analysis and synthesis of speech, the National Institutes of Health defray the costs of sharing the facilities with investigators from other institutions—support that continues for nearly twenty years.

Harris, working with Fredericka Bell-Berti, Gloria Borden, and others, demonstrates electromyographically how the precise phasing and layering of articulatory actions give rise to segmental overlap, and thus to the acoustic phenomena of coarticulation.

Isabelle Liberman, Shankweiler, and Alvin Liberman team up with Mattingly to study the relation between speech perception and reading, a topic implicit in the Laboratories' research program since the 1940's. They develop the concept of "phonemic awareness," the knowledge that would-be readers must have of the phonemic structure of their language if they are to learn to read. Under the broad rubric of the "Alphabetic Principle," this concept is the core of the Laboratories' program of reading pedagogy today.

Patrick Nye joins the Laboratories to lead a team including Cooper, Jane Gaitenby, George Sholes, and Gary Kuhn in work on the reading machine. The project culminates when the addition of an optical typescript reader enables investigators to assemble the first automatic text-to-speech reading machine. By the end of the decade the technology has advanced to the point where commercial concerns assume the task of designing and manufacturing reading machines for the blind.

Working with Bruno Repp, Virginia Mann, Joanne Miller, Douglas Whalen, and others over the next decade or so, Alvin Liberman conducts a series of innovative experiments to clarify and deepen the concept of a speech mode of perception. These experiments move away from the cue as a static property of the acoustic signal toward the cue as a dynamic index of articulatory action.

Experiments by Peter Bailey, James Cutting, Michael Dorman, Quentin Summerfield, and others cast doubt on the validity of the "acoustic cue" as a unit of perceptual function. Building on these experiments, Philip Rubin develops the sinewave synthesis program used by Robert Remez, Rubin, Pisoni, and colleagues. These researchers show that listeners can perceive continuous speech, without traditional speech cues, from a pattern of three sinewaves that track the changing resonances of the vocal tract. Their work paves the way for a view of speech as a dynamic pattern of trajectories through articulatory-acoustic space.

Rubin, Thomas Baer, Paul Mermelstein, and colleagues develop Mermelstein's anatomically simplified vocal tract model into the first articulatory synthesizer that can be controlled in a physically meaningful way and used for interactive experiments.

1980s

Studies of different writing systems over the next two decades support the controversial hypothesis that all reading necessarily activates the phonological form of a word before, or at the same time as, its meaning. Work includes experiments by George Lukatela, Michael Turvey, Leonard Katz, Laurie Feldman, Ram Frost, and others in the Roman and Cyrillic alphabets of Serbo-Croatian, by Shlomo Bentin, Frost, and Katz in Hebrew, and by Mattingly and Feldman in Chinese.

Several researchers undertake to develop compatible theoretical accounts of speech production, speech perception and phonological knowledge:

• Carol Fowler proposes a "direct realism" theory of speech perception: listeners perceive gestures not by means of a specialized decoder, as in the motor theory, but because information in the acoustic signal specifies the gestures that form it.

• Inspired by Turvey's earlier work on "action theory," Carol Fowler, Rubin, Remez, and Turvey propose a theory of speech production in which phonetic goals (such as closing the lips, raising the tongue or opening the vocal cords) are achieved by transient, special-purpose organizations of the articulators, termed "coordinative structures" or "synergies."

• Scott Kelso and colleagues demonstrate functional synergies in speech gestures experimentally. When one articulator in a synergy is perturbed (when the jaw is tugged down, for instance, as the lips close to form /b/), other articulators (in this instance the lips) automatically compensate to achieve lip closure.

• Elliot Saltzman develops a dynamical systems theory of synergetic action and implements the theory as a working model of speech production, in which actions of the articulators are gestures that form and release constrictions in the vocal tract.

• Linguists Catherine Browman and Louis Goldstein develop the theory of "articulatory phonology," in which gestures are the basic units of both phonetic action and phonological knowledge. The associated "linguistic gestural model" generates appropriately phased patterns of gesture for words in English. These "gestural scores," assigned dynamic values by the Saltzman model, drive the articulatory synthesizer of Rubin and Mermelstein to produce intelligible speech.

Alvin Liberman and Mattingly revise and update the motor theory, recasting it in an explicitly biological frame. They posit a specialized "phonetic module," encompassing both production and perception, analogous in some respects to modules for sound localization in the bat, the barn owl, and humans. The revised motor theory remains viable, though controversial, today.

Giuseppe Cossu, Isabelle Liberman, and Shankweiler are among the first to present evidence that difficulties in acquiring phoneme awareness and ensuing problems in word recognition characterize reading disability across different languages that use an alphabet.

Shankweiler, Stephen Crain, Mann, and Paul Macaruso present evidence that language comprehension difficulties associated with reading disability are typically based on processing limitations, not deficiencies of grammatical knowledge.

Bell-Berti shows that vocal tract configurations underlying a given phonological contrast (consonant voicing, for instance) entail active (or passive) engagement of all the articulators, not only those effecting the contrast.

Borden and Harris publish *Speech Science Primer*, a graduate and advanced undergraduate introduction to speech science. First published in 1980 and later revised in collaboration with Lawrence Raphael, the book is now in its fourth edition.

1990s

Harris and Bell-Berti show that the cohesion of gestures forming certain phonetic segments (tongue and lip gestures in English /u/, for example) rests on their invariant phasing with respect to one another. This finding is consistent with the hypothesis that segments arise as units of phonetic function by integrating established gestural routines.

Kenneth Pugh is among the first scientists to use functional Magnetic Resonance Imaging (fMRI) to reveal brain activity associated with reading and reading disabilities.

Continuing research begun in the 1980s, Catherine Best elaborates on the finding that infants begin life able to distinguish the sounds of many languages, but within little more than six to ten months tend to lose the capacity to discriminate some sound contrasts not present in the language spoken around them. (Intriguingly, they retain the ability to discriminate others.) She develops the “direct realist” Perceptual Assimilation Model to predict the effects of language experience on speech perception in both infants and adults.

Rubin, Goldstein, Mark Tiede, and colleagues design a radical revision of the articulatory synthesis model. Their three-dimensional model of the vocal tract permits researchers to replicate fMRI images of actual vocal tracts and the articulations of different speakers. Whalen, Goldstein, Rubin, and colleagues extend this work over the next decade to study the relation between speech production and perception.

Weijia Ni, Pugh, Shankweiler, and colleagues at Yale develop novel applications of neuroimaging to measure brain activity associated with understanding sentences. With Einar Mencl, they are also among the first to extend this method to the study of individuals. Shankweiler, Susan Brady, Anne Fowler, and others explore whether weak memory and perception in poor readers are tied specifically to phonological deficits. Evidence rejects broader cognitive deficits underlying reading difficulties and raises questions about impaired phonological representations in disabled readers.

Alvin Liberman publishes *Speech: A Special Code*, reprinting twenty-five key Haskins papers from the past forty-five years with an introductory essay describing their intellectual origins and theoretical implications.

2000s

Anne Fowler and Brady launch the Early Reading Success Initiative, a demonstration project examining the efficacy of professional development in reading instruction for teachers of children in kindergarten through second grade.

Whalen and Khalil Iskarous pioneer the pairing of ultrasound, which monitors articulators that cannot be seen, and Optotrak, an opto-electronic position-tracking device that monitors visible articulators, to record vocal tract activities less invasively than other technologies. The resulting images give a fairly complete picture of the vocal tract in action, opening the door to research on the links between production and perception that has hitherto been too cumbersome or costly.

David Ostry explores the neurological underpinnings of motor control by adapting a robot arm to influence jaw movement. The “Phantom” robot arm tracks the jaw—and applies forces to it—in three dimensions in real time, allowing examination of the control of the jaw during speech and other activities. The Mastering Reading Instruction program, a large-scale experimental project led by Brady and Margie Gillis, focuses on professional development in reading instruction for first grade teachers. Funded by the U.S. Department of Education’s new Institute of Education Science, the project applies thirty years of Haskins research on reading acquisition and reading difficulties to study ways to train teachers in effective methods of reading instruction.

Studdert-Kennedy and Goldstein propose a theory of the evolution of phonetic capacity. From children’s speech errors and patterns of phonological development, they argue that a neuroanatomically differentiated vocal tract coevolved with vocal imitation, a capacity unique among primates to humans.

David Braze and Shankweiler develop an eye movement laboratory for investigating reading processes in normal and disabled readers. Eye movement recordings are now being studied in coordination with brain activity measures.

In March of 2005, Haskins moves to new quarters with 23,000 square feet on the ninth floor of 300 George Street in New Haven, having outgrown the capacity of 270 Crown Street, where it resided for 35 years. The new facilities provide additional state-of-the art laboratories, including an Infant Lab. The ribbon-cutting ceremony is scheduled for May 9, 2005, and a 70th anniversary symposium planned for the 2005-2006 academic year.

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