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Infant Science

A UW couple leads our new thinking
about babies' amazing minds

HOW DO BABIES learn to talk?

*Somuchstuffwaftspasttheirrears longwigglywavesof soundstreamingfromabagofskin
withtwobigdots constantlyswiveling andacavernthatgoes opendosependose
SuWHEEE Tee! ArrrrreyocouMMMMAAmaaaZZ swEEEEtBAAAyBeEE?*



In a soundproof electrically-shielded booth, researchers prepare to see whether Milo Mighdoll is still a "citizen of the world," able to hear all the sounds of every language. He'll lose that ability as his brain commits to a native language around his first birthday. He's held by his mother, Jacqui Friedman Mighdoll, while Maritza Rivera-Gaxiola hooks up computer wire and Lindsay Klarman distracts him with a doll.

How to decipher what's syllable? What's smile? What's significant? What's sneeze?

For eons, babies have been routinely cracking the speech code. For almost as long, nobody thought much of that feat, or of infant intellect, except, perhaps, their mothers, who sensed those first words were pure genius, but not appropriate to brag about in the supermarket, and certainly not the basis for revolutionary scientific research.

Then came clever experiments to figure out what babies know and when. Would just-born babies imitate when an adult stuck his tongue out? Yes! Without ever seeing their own faces, newborns come into the world knowing they are like other humans.



Between experiments, Sofia Martin-Fourooohi wanders the halls at the Institute for Learning & Brain Sciences, examining photographs of the human brain.

Then came other tools to peek into the infant mind: video, audio, computer synchronization, the electroencephalogram (EEG), functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), a tower of machinery dubbed "the hairdryer from hell." For the first time, scientists could precisely tell what babies watch, how they sort sounds, whether foreign languages resonate, when "critical windows" of learning open and close, what infants understand about other people's actions, likes, dislikes and intentions. We are beginning to understand how we learn to care about each other.

Most startling? Babies are smarter than the rest of us.

Baby-brain research, once the Home-Ec of sciences, is now hot — a topic that trumps biotech and global health at Seattle dinner parties and lands researchers millions in funding, appearances on talk shows, and invitations from both Presidents Clinton and Bush to White House conferences on early childhood education.

Another measure of the field's rise: The University of Washington last year devoted prime waterfront real estate to the new Institute for Learning & Brain Sciences. The old brick fisheries building is now home to an interdisciplinary center co-directed by professors Patricia Kuhl and Andrew Meltzoff.

Considered a top lab of its kind, I-LABS collaborates with scientists in Finland, Japan, Mexico and 37 other countries, last year pulling in more than \$4 million in funding, and was also part of a consortium awarded a coveted \$25 million Science of Learning grant from the National Science Foundation. Hallway bulletin boards flutter with papers published in the prestigious journals *Science* and *Nature*, as well as glossy pop magazines featuring wise-eyed babies wearing polka-dot electrode caps.

The questions: What do babies know about language, when do they know it, and what's the best time for them to learn it? Can babies learn from television? Can we know something about who we're going to be by looking at a little baby? "That's as fully important as sending rovers to Mars," Meltzoff says.



Three-year-old Sofia Martin-Fourooohi sticks her foot on the table when asked by post-doc researcher Dan Bernstein to show which footprint is her size. He's testing the "I Knew It All Along Effect," or hindsight bias, the way children revise their theory of the world as they soak up new information. Andrew Meltzoff watches the test from another room along with Sofia's mother, Nohl.

Kuhl and Meltzoff, who happen to be married, share a certain glamour that comes with being at the top of their fields in a science ripe for breakthroughs. After the space-age '70s, the software '80s and the biotech '90s, perhaps the science of the millennium belongs to baby brains — and Kuhl and Meltzoff are proud parents.

Both ooze charisma and intelligence. At 54, Meltzoff is a curly-haired surfer who studied developmental psychology at Harvard and Oxford. He visited and was influenced by the brilliant biologist and philosopher Jean Piaget in Geneva, and later refuted some of Piaget's theories.

Kuhl is considered the world's leading authority on speech development. She's possibly the only scientist elected to the august American Academy of Arts and Sciences who could also hold her own in a James Bond movie. At 58, Kuhl is very blonde, very designer, very trim — without exercising. She drives a taupe Jaguar and jets around the world lecturing and overseeing research.

At home, incoming e-mail blinking on the Blackberry clipped to her apron, she races to cook dinner before her daughter returns from swim practice, a task that involves seasoning tenderloin while negotiating a contentious conference call with other scientists. Yet the real stars, Kuhl and Meltzoff say, are the babies.

To them, a baby is a scientific miracle, the best learning machine on the planet, more powerful than the most advanced supercomputer, able to learn languages faster and better than adults, quick to recognize and manipulate the social cues that govern everything from war to animal cookies.

Born with 100 billion neurons, about the same number as stars in the Milky Way, babies suck in new information and statistically analyze it, comparing it with what they've previously heard, seen, tasted and felt, constantly revising their theories of the world and how it works. By 3 years old, babies have about 15,000 synapses per neuron, three times the synapses of adults. That's one of the reasons it's easier to learn foreign languages when you're young. But pruning neural connections at key times, much as gardeners prune roses in late winter, is also critical so the brain isn't overwhelmed with extraneous information and can focus on what's important.

"The brain prepares itself to learn things at a certain time," Kuhl says. "Communication and social relations are early, because in order to maneuver in the world, to survive as a hominid, you had to relate to the other hominids."



Patricia Kuhl lectures to University of Washington students about where and how the brain maps language. Babies are born with 100 billion neurons, about the same number as stars in the Milky Way. By 3 years old, they have about 15,000 synapses per neuron, three times the synapses of adults. That's one reason it's easier to learn foreign languages when you're young.

PATRICIA KUHLL WAS born into a German Catholic family in South Dakota, the second of five children. Kuhl's mother, an excellent seamstress, had a sixth-grade education; her father was the first in his family to attend college, later stringing together jobs as sewing-machine salesman and chemist.

"There was barely enough food on the table," recalls older sister Delphine Sexton, and the kids had to change schools often when the family moved. Still, Pat was always outgoing. She was a cheerleader, took free voice lessons from the nuns after her family could no longer afford the 25-cent fee, cashiered at the Piggly-Wiggly store starting at age 16.

The Kuhl sisters were encouraged to become nuns, but Kuhl's father also told Pat she'd make a good lawyer. "Dad was an education advocate," Kuhl says. "He always said: You can do anything you want to do if you work hard."

In college at St. Cloud State in Minnesota, Kuhl considered majoring in philosophy and math until a professor told her it would be weird: all the world's philosophers were men. She turned to psychology and speech and hearing, her interest sparked by a niece who was deaf. "I fell in love with language," Kuhl says. "I thought it was a pretty good mystery."

In graduate school at the University of Minnesota, she studied which parts of the brain were responsible for language by thinly slicing the gray matter of human cadavers who had suffered aphasia and strokes. Then she applied questions about language and neurobiology to chinchillas and monkeys, demonstrating that they initially decode the sounds of language the same way babies do, by hearing auditory "edges" (similar to the way we see visual edges signaling, say, where a cup ends and the table begins).

Kuhl's findings, published in 1975 in *Science*, were shocking and unpopular. "We humans think our language is unique," she says. "But evolution arranged it so babies came into the world with no trouble hearing distinctions and sorting out sounds."

Kuhl forged ahead, undeterred by critics or the dearth of other women in acoustics. (As a post-doc in St. Louis, she had to walk down three flights to find a ladies room.) She completed her Ph.D in three speedy years, was promoted to full professor at the UW in five. Along the way, she showed that adults naturally use high-pitched, lilting "mother-ese" to help teach babies language; and that babies are "citizens of the world" when they're 6 months old — able to hear all the sounds of every language — but lose that ability by their first birthday as their brains commit to a native tongue.

Heady stuff, but hard at home. "The life of a scientist is murderous," Kuhl says. Her first marriage of 12 years didn't last. "In high-flying labs, how many hours after midnight? It's an enormous strain."



Pat Kuhl and Andy Meltzoff fell in love at the University of Washington while working on an experiment to measure whether babies match lip shapes with vowel sounds. After publishing the result in *Science*, they married and had a daughter. Now that she's almost grown, their new "baby" is the 1-year-old I-LABS research center, which they co-direct.

MEANWHILE, ON THE Jersey shore, Andy Meltzoff spent idyllic childhood summers becoming a champion surfer at his family's beach home. His mother was a reading teacher, his father the chief clinical psychologist at a New York City veterans hospital.

As a Harvard undergrad, Meltzoff was mentored by Jerome Bruner, a developmental

psychologist instrumental in founding the Head Start program. Bruner believed developmental psychology could not only answer age-old questions about the mind but also help transform society.

"When I knew Andy, he was a golden boy, Harvard, handsome, smart," plus he made a major scientific discovery at 27, says Alison Gopnik, a professor at the University of California, Berkeley, who met Meltzoff during graduate school at Oxford, when they'd float in a punt on the River Cherwell and he'd talk about his dream of an enormous center where scientists could do developmental, computational and neuroscience research with plenty of money and no bureaucracy.

Meltzoff's discovery, that newborns will stick out their tongues to imitate adults, demonstrated a connection between self and other from the moment of birth. "We're a role model for babies from the moment they look up at us and begin to sculpt their own activities according to what they see in the culture around them," Meltzoff says. This rocked the foundations of developmental psychology. Piaget, Sigmund Freud and B.F. Skinner had taught that newborns were social isolates with no knowledge of other people when they came into the world.

"Everyone was going to have to go back to the drawing board," Gopnik says. "There was a lot of resistance, and that can be hard to face, but Andy completely persisted. He would just do the next experiment, showing it over and over. Sometimes, when you have someone who's golden early on, they kind of crumble. Andy kept going."

At the UW, Meltzoff re-created his tongue-imitation experiment with newborns as young as 42 minutes. "I'd be home sleeping and the phone would ring: 'Dr. Meltzoff, your subject has arrived!' And I'd rush to Swedish hospital."

Not long after Meltzoff moved to Seattle, Gopnik noticed he was taking off in other ways. All of a sudden, in his Spartan bachelor apartment, there were lavender pillows. A potted plant. "Wait a minute," Gopnik says, "I think there's a woman here, and I think she's blonde!"

"When you're a married woman with a good friend who's a bachelor, you'd really like him to settle down and get married and be happy," says Gopnik, who would later co-author "Scientist in the Crib" with Meltzoff and Kuhl. "I thought it would be really tough with Andy because he was not going to want to marry someone who wasn't at least as good, if not a better, scientist than he was, and given that he also likes attractive blonde women who have papers published? Pat might have been one of the very few people in the world who fit those conventions."

At first, Meltzoff and Kuhl both claim, it was all about science. Something about whether babies connect faces with voices and match lip shapes with vowel sounds. In the experiment, a baby sat in front of two monitors. On one, Pat's face silently mouthed "ah ah ah," on the other, "ee ee ee." Then the loudspeakers would play "ah ah" or "ee ee." Even babies as young as 16 weeks would gaze at the face mouthing the corresponding sound. The study proved babies lip read, that language is not an isolated auditory process. It's a social act.

Setting up the experiment took a year and a half, and countless discussions in Italian restaurants. "We hovered over every data point like a grandparent hovering over the family recipes," Kuhl says. After surviving the arduous test of publishing their findings in *Science*, they decided to marry.

When their daughter was born 18 years ago, they decreed: "No experiments on Katherine Meltzoff!"

"At 40," Kuhl says, "I felt like, OK, I've joined the universe now. I felt like one of the gang. In a

grocery store, I'm in that fellowship of females that copes with the joys, the wonder and downright exhaustion and fear you have as a parent. It felt regular. Yet I had this niche knowledge."

Standing in line at the Queen Anne Starbucks, Kuhl heard 8½-month-old Kate babble. But not just any babbling. "Listen! She went bababababa!" Kuhl shouted to the barista making her extra-hot, foamy, grande latte. "Did you hear that? That's canonical babbling! That's what every baby does at about this time, and my kid just did it!"



Ouch! When adults see another person in pain, the anterior cingulate cortex lights up on Functional Magnetic Resonance Imaging tests. That's the magic place in the brain that literally allows you to feel another person's pain.

PARENTS, DON'T panic. You needn't rush out to buy Mozart and Baby Einstein DVDs. There's no scientific research showing commercial products will make babies smarter, happier or more compassionate.

What works, Kuhl and Meltzoff say, is doing what you naturally do: Talk, coo, play and cuddle with your baby in a loving way. *Grownups are designed to behave in ways that will allow babies to learn*, they write in "Scientist in the Crib." *For human beings, nurture IS our nature. Our unique evolutionary trick, our central adaptation, our greatest weapon in the struggle for survival is precisely our dazzling ability to learn when we are babies and teach when we are grownups.*

"When you watch parents in relaxed settings, they do the right things," Kuhl says. "Mother-ese falls off their tongues. When adults are stressed, communication falters and social interaction falters."

Day care? "Groups have always reared children," Kuhl says. "The quality of day care matters, but if there's a small ratio of kids to caretakers, the critical social stuff happens, language happens."

Television? "Should a child be in front of a TV eight hours a day? I'll go on record: No." But, Kuhl says, we need more studies on how much TV is too much; whether certain programming can teach certain things at certain ages.

Clearly, babies learn best from humans. But why?

On the second floor of I-LABS, 9-month-old Milo Friedman Mighdoll is plopped on the floor, playing with a rainbow sphere as post-doctorate fellow Juan Silva-Pereyra reads aloud from a book about a polar bear. In Spanish. A language Milo hasn't heard before.

Juan points to the polar bear's nose. *¡Su nariz!* Milo's big brown eyes and chubby cheeks turn toward Juan, then to the bear's nose, then back to his sphere. *¡La mariposa!* Milo looks briefly at the butterfly flitting across the page, then back to the ball.

Three months ago, Milo, like all babies, was able to distinguish all 600 consonants, 200 vowels and 40 phonemes found in Spanish, Salish, Senegalese and every other language. On Milo's first birthday, he'll likely hear only the sounds common to English as his brain commits to his

native tongue. The Spanish experiment is designed to see whether brief exposure to foreign language during a "critical window" will help Milo retain his ability to hear the "duh" "tuh" phonemes particular to Spanish.

Kuhl's earlier research found that 9-month-old American babies who played games with and were read to by Mandarin speakers could still hear Mandarin phonemes at 14 months after only a dozen 25-minute Mandarin sessions. A control group could not. Babies who were exposed to videotaped Mandarin could not.

So why does human connection make a difference?

"The hypothesis is that interaction is what sets the brain up to acquire learning," Kuhl says. "It's an opening of the cellular floodgates . . . There's this arousal thing . . . that might do something biochemically that allows cells to acquire information in a more memorable way. We know that hormones play a role. We know that when children are apprehensive, under stress, they don't learn."

This is where Kuhl's work in language intersects with Meltzoff's research on imitation, social interaction and gaze.

Meltzoff's theory, based on earlier experiments: The sooner a baby follows the gaze of an adult, the quicker they'll learn language. "Say Mom looks up at a bird in the sky and says, 'Bird!' Baby knows that's a bird," Meltzoff says. "Eyes are the window to the soul. For many reasons, it's important to pay attention to where people are looking. *Look!* Mom's upset. What's she upset about? Where's she looking? People wear their emotions on their eyeballs."

Which leads to Meltzoff's theories on empathy. The newborn-tongue experiment proved babies understand the connection between self and other. Another Meltzoff experiment, with 18-month-olds, demonstrated babies understand other people's intentions. The babies watched adults try to pull apart a toy that had secretly been glued shut. Given the same toy, but not glued, the babies completed the task.

Those elements, Meltzoff says, are the roots of empathy. "Human beings are special in the animal kingdom, because we feel empathy for one another and have a theory of mind that says we believe other people have beliefs, thoughts, intentions, emotions, desires that are like mine but not the same. We don't think cats and dogs and fish are capable of that.

"The moral implications of this are profound. That person is thought to be like me. If they act like me, have feelings like me, then maybe they should be treated like I want to be treated."

Meltzoff's latest work, published recently in *NeuroImage*, shows there's a special part of the brain where people "feel" other people's pain. Behind the forehead's center, the anterior cingulate cortex lights up on fMRI scans in adults who are shown pictures of other people stubbing their toes or smashing their fingers.

Of course, there are vast differences between individuals. Some can't stand to see suffering; others don't give a rip. "The next step is about intervention," Meltzoff says. "What part of the cultural environment makes some people more compassionate?"

This is where the whys of science morph into what-to-dos. Some of I-LABS' work, using babies' reaction to mother-ese, already helps diagnose autism in young babies, which means earlier treatment, a key to better outcome. Other research may suggest interventions for babies who lag in cracking the language code, or strategies for

babies in families under social or economic stress.

Scientists are still at least eight years away from bridging baby-brain research and the chalkboard, Kuhl says, but already, research suggests it might be more effective to teach foreign language in preschool, when children's brains are still plastic, than in high school, when it's traditionally taught. I-LABS hopes to fund a longitudinal study to see what factors in infancy make a difference in learning as children grow.

"Scientists do research on questions that matter so they can use it when sculpting policies that will help children," Meltzoff says. "At a certain point we get to the water's edge and we hand off to the politicians."

From there, what happens in the larger society may be just as complex, but not nearly as wondrous, as the inner workings of the tiniest minds.

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