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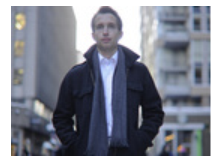
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The brain: How children learn language

July 16, 2010

JOSEPH HALL

HEALTH REPORTER

Mikhaiel Barnes is watching *SpongeBob SquarePants* as two University of Toronto psychology grads set up a mesh of 33 sensors on top of his buzz-cut head.

RICK EGLINTON/TORONTO STAR

Neuroscience student Kaja Jasinska measures blood flow in the brain of 10-year-old Mariam Barnes during research at the University of Toronto's Scarborough campus.

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Almost oblivious to the unusual gear that Marissa Malkowskie and Kaja Jasinska are affixing to his cranium, the 8-year-old stares resolutely at a computer screen, where the absorbent and yellow cartoon character is wreaking his usual havoc on the seabed town of Bikini Bottom.

But soon, the screen will begin flashing simple word sequences — paid, ring, hog, market — which the boy will be asked to read aloud into a microphone.

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And as he reads, the "near-infrared spectroscopy" sensors will shine their harmless light through his skull, 2.5 centimetres into his cerebral cortex, to the places where human language lives.

Today's experiment, conducted in the comparatively opulent labs of Laura-Ann Petitto, a cognitive neuroscientist at the U of T's Scarborough campus, is part of a groundbreaking research project that is comparing key brain activities of bilingual children and unilingual ones like Mikhaiel.

But over her career, Petitto has made startling discoveries into childhood language development as it unfolds over months and years.

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Petitto is the first researcher to actually witness the fact that specific parts of children's brains correspond directly with dusty categories of linguistics, like syntax and phonetics. She has shown that, as theorists such as Noam Chomsky were postulating more than 50 years ago without empirical support, these brain areas are innately wired to recognize and process different parts of language.

From the moment the first breath bathes it with oxygen to the time when adolescent hormones begin to bombard it, a child's brain is a growing, transforming, miraculous learning machine.

"The most amazing and awestruck processes occur during these years," Petitto says. "That doesn't mean that the rest of life isn't fascinating as well; (neural) development across the lifespan is amazing.

"But the remarkable forces that thrust us into being a human being are really blossoming during this period of human life. This is it. This is where the action is in human development."

And the most amazing, the most human of these actions, Petitto argues, are the physiological processes of language acquisition.

"It's the most powerful way we, as humans, can travel the universe without leaving our seats."

It was long held, even into the 20th century, that we were born with the brains we would live with, that the physiological organ was a fait accompli upon delivery.

But in the first few years after birth, it's now certain, the brain can double in size, says Margot Taylor, director of functional neuroimaging at Toronto's Hospital for Sick Children.

"The period of childhood sees the most growth of the brain, and there's a tremendous increase in the first years of life . . . with all the complexity of the brain structures increasing."

It's during childhood that the vast majority of our neural pathways are laid down and cemented in a process known as myelination, Taylor says.

Myelin, the brain's white matter, coats the newly laid axons — the organ's wiring — that carry the memories, knowledge and skills accumulated during childhood, ensuring the electrical flow that encodes them runs as smoothly and rapidly as possible.

As well, she says, the synapses and dendrites that transmit and receive those electrical signals via the axons sprout up at tremendous rates until age 10.

Much of this growth is directed by experience, with the brain changing and expanding to accommodate the new ideas and demands that the world imposes.

"Every time you learn something, if you remember something, your brain's changed," Taylor says. "And as you're learning a huge amount of stuff over childhood, your brain is changing rapidly."

Learning a musical instrument, for example would actually produce changes in the auditory and motor cortices of the brain, expanding those regions beyond their normal growth.

But it's the language-linked parts of this brain development that interest Petitto.

Petitto's seminal breakthrough in her pursuit of language development may well have been a technological one. She pioneered the use of functional near-infrared spectroscopy (fNIRS) in the search for language's neural nursery.

Actually, the technology is old, as imaging equipment goes. Dating back to 1979, it is used extensively in cardiology and breast cancer clinics and in premature baby wards, where it monitors blood flow inside infants' delicate heads.

But Petitto saw the potential to use fNIRS to study the brains of young children and the physiology of language.

The technology sends infrared signals into the outermost layer of the organ, its undulating cortex, where higher

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Cute kid quote of the week

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thought occurs. It then captures that light as it bounces back. And if the original signals have encountered the rush of oxygenated blood that feeds electrical activity in the cortex, the colour of the signals' echo is altered in a detectable way.

By correlating specific language activities of subject children with the neural tissues that are drawing the most blood at the time, Petitto can map those linguistic functions to specific parts of the brain.

What is the nature of consciousness? How do we reason, think and plan? What is the essentially human experience?

The scientific answers to all these questions lie in a tangle of synaptic pathways that flash and fire like whispers of lightning through the cerebral cortex.

But for Petitto, the key question, the paramount piece of our humanity to pursue and explain, is the profound mystery of language.

How do we learn language? And where, in the brain, does it reside?

The fNIRS are allowing Pettito to pursue her inquiry into what happens in the brain during language acquisition, and how "that miracle get(s) accomplished by the time a child is 3-years-old."

Petitto's research follows the framework of academic linguistics, and such categories as phonology, morphology, syntax, semantics, discourse and pragmatics.

"The really cool thing is that each one of these parts of (linguistics) has discreet brain tissue that's associated with doing that job," Petitto says.

"The parts of human language that the linguistic scientists had discovered and identified are indeed, amazingly, the way the human brain carves out its tissue. It's psychologically real, not just linguistic gymnastics."

And with her fNIRS, Petitto can track each linguistic piece as it comes online in baby and toddler brains. The pieces come online in a predictable order, and at defined times, she says.

"We see it, and we sit there like a theatre or a musical concert," Petitto says. "We watch the bass come in and the second fiddle come in, we watch all the parts of the orchestra come in to produce this miracle we call language."

This overture to language is staged largely within three segments of brain just above and in front of the left ear.

The first to spring to life, the left superior temporal gyrus, recognizes the phonemes that an infant begins to babble a few months into life.

A finger-like wedge of neural tissue, the LSTG takes the "mush" of sound that streams into a baby's ears each moment and plucks out the phonological bites that make up a native tongue.

Those chunks are then shunted forward to the left inferior frontal gyrus, which comes on line next. The LIFG is itself segmented into different tissues, with specific linguistic roles.

One segment assembles the sound bites into words, while another, called Broca's area, looks up their meaning and figures out things like verb tense — a process known as morphology.

"Is this an 'ed' that is past tense meaning 'I skipped,' or is this an 'ed' meaning Ed, my friend's name?" Petitto explains.

A third LIFG segment looks up the patterns in which the words are strung together, or syntax.

And these linguistic milestones follow a fairly rigid timetable, Petitto says.

"At six months babbling comes on in speech, 12 months the first word comes on, 18 months the first two word (couplings) appear, 24 months the first morphological markings.

"By 30 months syntax is there, the kid is basically done. The rest is refinement."

The physical reality of linguistics in the brain was supported by one of Petitto's earliest experiments, which showed that even profoundly deaf babies pick up languages in the same ordered manner.

At that time, the prevailing view had been that it was speech that imposed language on to children externally, and that the baby's babblings and first words simply corresponded to the growing physical capacity of the mouth to utter them.

"The reason you see babbling come first," Petitto says of the traditional view, "is that's when the vocal tract first attaches to the back of the larynx and the jaw can drop, allowing the air to be pushed out and you have 'ba, ba, ba.' "

But by this reckoning, children with no speech to guide them — those born profoundly deaf — should learn language differently, Petitto says.

In a 1991 study published on the cover of the journal *Science*, however, she showed that children learning sign language and those exposed to speech hit every language milestone at precisely the same times.

Children learning to sign even did the equivalent of babbling with their hands as they picked up the phonemes of their visual tongue.

"The fact that you have sign language and the fact that you have speech coming in exactly the same time . . . meant 'Oh my god, something in your genetic makeup is governing it,' " Petitto says.

Hearing children face an environmental problem that deaf children don't, namely, how to pluck language out of the cacophony of noise that often accompanies it.

"They pop out of the womb, there's a whole bunch of stimuli, it's bombarding them, and all of a sudden, the baby has to find the (human sound) chunk."

But infants are wired to recognize the bite-sized phonemes, the pas and bas, that make up words.

And, in another research advance, Petitto found that babies can pick out these sounds as long as they are delivered by humans speaking in sound frequencies of 1.5 hertz.

"This stuff comes in and for free, it chunks the information for the baby like a sausage machine —– chunk, chunk, chunk, link, link, link," she says.

Located in the left superior temporal gyrus, the phoneme-capturing tissue lights up on Petitto's scans each time sounds in that 1.5 hertz frequency range are played.

"We're a gorgeous, fine-tuned social unit," Petitto says.

"The world gives us the (human) nugget, and we have brain tissue that's there to receive our nugget. It's like a lock and a key."

Petitto's discovery debunked more than 125 years of anatomical thinking, which held that the LSTG tissue had sound-capturing capacity alone. She showed it also lit up in deaf people when hand-generated pieces of sign language were delivered at 1.5 hertz frequency.

The filtered-out phonemes, of which there are about 44 across all languages, are then forwarded from the superior to the frontal gyrus, which reassembles them back into words and gives them meaning as the child learns.

In the smallest infants, the ability to pluck out these finely tuned human sounds works across all the world's languages, each of which has unique phoneme cadences and pronunciations, Petitto says.

"No fetus knows if it's going to grow up in New Jersey or grow up in Tokyo. So a human child from birth to six months has a universal capacity to discriminate any of the speech sounds in any of the world languages that it could have been exposed to."

Between six months and a year, however, this capacity is diminished in one of the few aspects of human brain development where a child goes from better to worse, Petitto says.

Instead, the capacity to distinguish the tiny variations in phonetics that are specific to the child's own language skyrockets.

"It's a beautiful dance between nature and nurture," she says. "You lose the universal capacity, but the flip side is you gain an increased capacity in your native language."

However, for children being raised in bilingual settings, the focus of Petitto's research these days, this capacity to capture universal phoneme variants does not close, she has found.

And babies learning two languages at once actually develop better vocabularies than their unilingual peers in either down the line.

Thus, rather than being a detrimental assault on an infant brain, as was long held by many in the field, early bilingualism gives children distinct advantages later in life, especially in reading, where an ability to recognize phonology is actually crucial.

Indeed, Petitto says studies she conducted of bilingual children from some of the poorest neighborhoods in the United States showed that their reading capacity was the equal of unilingual kids from the country's wealthiest enclaves.

Aside from its obvious scientific interest, Petitto's work holds the potential to help diagnose and treat language problems in very young children, before they can even speak.

For example, Petitto says her scans might be used to look for abnormalities in the functioning of the LSTG during infancy, which could signal that the child could have phonological problems when it begins to speak or read.

By that time, it might be too late to fix things, she says, with myelination of critical speech pathways having already been laid down.

"But with this knowledge, we can develop more targeted therapies," Petitto says. "You know exactly the nature of the language problem, which brain tissue is doing it."

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