Neurological Connection to Language Acquisition

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Today we’ll be talking about the role neurology plays in learning language, whether it is your first or second language.
Brief Historical Background on Neurological Development and Language Acquisition

- Broca and Wernicke
- Chomsky
- Lenneberg
- Petitto
Lateralization of the brain: In human beings, it is the left hemisphere that usually contains the specialized language areas. While this holds true for 97% of right-handed people, about 19% of left-handed people have their language areas in the right hemisphere and as many as 68% of them have some language abilities in both the left and the right hemispheres.

References:

Paul Broca and Karl Wernicke

- Paul Broca and Karl Wernicke developed theories of brain lateralization.
- They proved that there are major areas in the left hemisphere of the brain responsible for language.
- Paul Broca was a French neurologist.
- Carl Wernicke was a German neurologist.

Broca (1861): The first language area within the left hemisphere to be discovered is called Broca's Area, after Paul Broca. Broca was a French neurologist who had a patient with severe language problems: Although he could understand the speech of others with little difficulty, the only word he could produce was "tan." After the patient died, Broca performed an autopsy, and discovered that an area of the frontal lobe, had been seriously damaged. He correctly hypothesized that this area was responsible for speech production.

Wernicke (1876): The second language area to be discovered is called Wernicke's Area, after Carl Wernicke, a German neurologist. Wernicke had a patient who could speak quite well, but was unable to understand the speech of others. After the patient's death, Wernicke performed an autopsy and found damage to an area at the upper portion of the temporal lobe, just behind the auditory cortex. He correctly hypothesized that this area was responsible for speech comprehension.

References:

Chomsky’s LAD contains four innate linguistic properties:

1. The ability to distinguish speech sounds from other sounds in the environment
2. The ability to organize linguistic data into various classes that can later be refined
3. Knowledge that only a certain kind of linguistic system is possible and that other kinds are not
4. The ability to engage in constant evaluation of the developing linguistic system so as to construct the simplest possible system out of the available linguistic input

References:


Eric Lenneberg

- Critical Period Hypothesis (1967)
- Hypothesized that there is a biologically determined period in which humans are able to acquire language more easily
- With other researchers determined that after age of 12 the critical period for language acquisition ends
- After Critical Period, language can never be learned in a normal, fully functional sense with native-like pronunciation

Examples of proof of a Critical Period:
- Genie “The Wild Child” – She was found when she was 13 years old. She had been abused her whole life, and had never acquired language. With a lot of work, she was never able to completely acquire language.
- Linguist Judy Kegl studied 300 adults in Nicaragua – They were raised in healthy environments, but never acquired language. Later, when kegl tried to work with them, they were unable to learn language in a meaningful sense – they could learn vocabulary, but not syntax.

References:


This brings us to Dr. Petitto, whose work will be the primary focus for the remainder of our discussion and will address current theories concerning the neurological basis for language acquisition.

She is known for her discoveries concerning how young human children acquire natural language, be it spoken or signed. She discovered that profoundly deaf babies exposed to signed languages from birth babble on their hands, which possesses the same syllable structure and occurs on the same developmental timetable as hearing babies' vocal babbling (1991), and that sign-exposed hearing babies raised entirely without speech also produce hand babbling that is rhythmically distinct from all other hand movements that all babies make (2001).

References:

There are two competing theories that Dr. Petitto’s group of researchers tackled.

First,
The syllabic structures produced by babbling

References:

The Motoric Hypothesis maintains that babbling is simply a byproduct of motoric development.

In contrast, Petitto and other researchers propose that babbling has a neurolinguistic foundation:

- Natural language rhythms determined biologically
- Babies babble to discover which sounds match the sounds of the language around them

There are three empirical pieces to Petitto’s puzzle used to address the question “To what can the origin of human language be attributed?” Petitto and her colleagues use these findings from three key experiments to hypothesize that there are biological, more specifically, neurological controls of language; that language is not solely learned from the environment, only shaped by it.
In the first of these three experiments, magnetic resonance imagining, or MRI, was used by Petitto’s group to measure and record the size of the cortical regions associated with auditory input. A group of hearing and one of deaf adults were used to look for deviations in the brain size of deaf individuals. What was assumed was that the area of the brain associated with auditory input in individuals who were deaf from birth would show known signs of limited or no use—that is, a degradation of brain tissues in the auditory region. However, what they found was that the anatomical structures were “preserved,” that there was no sign of deterioration in the brains of those with congenital hearing loss.

You can see that the two columns, the left column which is that of a deaf individual and the right of a hearing, show no significant variation in appearance between the two representative MRI scans of the brain.

To Petitto, this suggested that there was a different basis for language development other than the fine tuning of motor skills, where a young child gradually gains more control over the motor functions controlling jaw muscles and the mouth, and subsequently determining the ability to produce language.

Blood Flow Activity in the Brain’s Linguistic Region

Petitto’s study found blood flow activity in linguistic region of the brains of deaf individuals during specific sign language communication.

The next piece of the puzzle for Petitto and her colleagues was demonstrating that neural activity in the language cortex of the brain was the same for both deaf individuals using sign language as it was for hearing individuals using spoken language.

They used PET scans to measure the blood flow activity in the brains of participants as they performed similar speech activities. What you see in the upper portion of the image is a comparison of the activity in the brain of deaf and hearing individuals. Notice that the color appears in similar regions of the brain.

This was, again, an indication to Petitto that production of language was coming from the same source in the brain regardless of the mode of language—spoken or signed.

References/image source:
Petitto’s final piece to this neurological puzzle concerned the babbling sounds that infants make around 7 months. This is a particularly active period of maturation for babies when there is an increase in motor and neurological activity and growth.

However, there is some debate over the source of babbling: what can babbling be attributed to? Is it a result of infants testing their motor skills: taking their jaws for a test-drive, so to speak? Or is there a biological mechanism controlling language development, and babbling is the product of a linguistic process in which the infant is trying to match the sounds from the whole spectrum of sounds humans can make to match with those from the “ambient” environment? In other words, are babies going through a process in which they are reducing the catalogue of sounds they will produce as well as the combinations of those sounds to match that of their parents?

MacNeilage and Davis attribute babbling to a babies’ testing of their motor skills and that the resulting language arises from increased abilities in a maturing baby to manipulate the jaw, mouth, tongue, and vocal cords.

While Petitto didn’t disagree that the motor skills of a baby improve during this period around 7 months, she just didn’t think that motor skills were driving babbling and the subsequent language acquisition. Rather, she and her colleagues felt that the ability to produce language existed in the brain apart from sound production via motor skills mechanisms; more specifically, they believed that a human’s brain came with, using Petitto’s analogy, a “robust index” of sounds and rhythms, phonetic and syllabic, that are narrowed as infants try to figure out how to produce the language they receive as input from
Petitto’s belief in the linguistic basis for language acquisition and not motor, in part, arises from her research concerning the sign language produced by deaf people. This research had been aimed at finding evidence to support the theory that sign language had the same source of production in the brain as spoken language; therefore, a true language like spoken languages.

But more importantly in the motor versus linguistic debate, to Petitto, this suggested that language was not acquired by means of motor skill development, but by a language capacity already existing in the brain; that sound production was not the basis for language.

To address the counter arguments put up by the proponents of the Motoric Hypothesis, she believed she needed to demonstrate that language definitely developed from something in the brain that did not require speech or sound production.

Photos: http://www.signingbaby.com/photo/cat.html
The Experiment: Do we already have rhythm?

Questions to answer:
- Does infant “babbling” occur in sign language?
- If so, is the origin of language linguistic?

Because babbling is the first perceived manifestation of organization in sounds during child development, researchers, including Petitto, have probed the basis for babbling as a means for discovering the origins of language.

What Petitto and her colleagues proposed was that the human brain by biological means has a preprogrammed capacity to recognize the rhythms that are built into natural languages and have nothing to do with sound production…and that these rhythms are first manifested in babbling.

From research different than mentioned earlier, Petitto and her colleagues had perceived distinct hand movements in deaf babies learning sign language that they deduced was babbling, but in sign language. So they wanted to test a theory that the hand movements they were seeing in these deaf babies were in fact organized hand gestures much like babbling made vocally appears to resemble the organization of phonetic units to create syllabic units in natural spoken languages. But they would test this theory only with hearing babies but in different language environments.

To prove that the distinct hand movements in these babies were in fact babbling and the beginning of signed language as well as confirming their belief that language was driven by biological development in the brain and not the development of motor skills, Petitto’s research group studied the production of babbling by two groups of babies—all hearing babies, but one group learning spoken language as their first languages and another group learning signed language…neither being cross-exposed to a systemized version of the other language form.


Pictures: 1) http://www.dartmouth.edu/~lpetitto/OELASummitTalk.pdf; 2) clip art file
Petitto’s research group used two means of gathering data:
First, they recorded all sessions (at 6, 10, and 12 months) on video tape. However, they chose not to view the tapes before collecting all data or at least not have the same people review the tapes as those processing the second source of data…

…which was the identification of locations and trajectories of hand gestures by both sets of babies, recorded by Optotrak sensors sensitive to the light emitted by infrared emitting diodes placed strategically of the hands of these babies. This provided an objective, quantifiable graphic of each participant’s hand movements.


Picture source: http://www.dartmouth.edu/%7Elpetitto/nature.html
What they discovered from the data was that there was a distinction in the distribution of hand gestures between sign language babies and spoken language babies.

Both groups made a variety of high frequency gestures that ranged in their location; that is, this particular type of high frequency (fast moving) gestures would occur most anywhere. This type of gestures can best be seen in the graphic as the high peak of the dotted line—these are the high frequency gestures of spoken language babies. So the dotted line represents gestures made by spoken language babies.

Notice there is only one pronounced peak for spoken language babies, in the high frequency range (this is data recorded by the Optotrak sensors).

What they discovered in comparing the Optotrak data, in particular the Optotrak data of hand location, to the video tapes was that these low frequency hand movements in the sign language babies resembled distinct placement and hand formation within typical sign language areas in relationship to the body as well as the beginnings of hand manipulation resembling the hand shapes of signed language.

Additionally, over that 6 to 12 month period these hand gestures reduced in the number of possible shapes expressed, just like the reduction in the range and combinations of sounds of the voiced babbling. Suggesting that the infants both manual and spoken were slowly limiting themselves to the possible rhythms and syllables of their parents, based on the input they received from their parents.

No, you don’t have to be Chaucer or Shakespeare to have rhythm!

- Manual gestures mirrored babbling of spoken babies
- Babbling and therefore language did not require motor skill development
- Suggesting language originates with biologically established language rhythms not bound by sound

What Petitto and her colleagues suggested that their findings pointed to was that the infants’ shaping and low frequency movements of their hands mirrored the babbling of spoken language children—a manual babbling not requiring or tied to the development of the motor skills controlling the jaw and mouth, nor the development of the vocal tracks. And that the babblings by the signing infants were their attempts to figure out which rhythmic patterns of language they were to use in the environment in which they were being raised.

In order for the hand babbling to take place, Petitto’s research group concluded that the expression of language can take any number of pathways—hand or vocal—but that the basis for language acquisition and maturation originate in the information already existing in the brain because of biological, that is, neurological development.


Snoopy animation: http://www.snowcrest.net/cafemocha/Snoopy.htm
A Few Questions to Ponder

1) How does knowing that language is not based on motor skills but on linguistic information in the brain change how we might approach teaching language learners?

2) How might we be able to utilize this information?

3) What else might we learn about language and language learning knowing that the information required to produce language, based on Petitto’s studies, appears to come from within us rather than the external world?

While this information may not help you make decisions in the day-to-day creation of lesson plans and plans for individualized strategies, it does give us a perspective on the origins of language and help us to ask questions about language instruction.

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Perhaps it is encouraging to know that we actually have the capability built into our brains to produce the sounds, syllables and rhythms of all languages, and that we only need to, perhaps, access that ability in order to learn new languages.

[Note: Petitto does not explore the neurological impact on accent—perhaps something for discussion based on what we learned in Brown]
Bibliography


