44 Language and the Social Brain: The Power of Surprise in Science

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In 2003, I discovered that when nine-month-old infants are exposed to a new natural language for twelve sessions over a month's time, that interaction with another human being is essential for infants to learn. A beautiful DVD presentation of the exact same material to another group of babies produced no learning whatsoever, nor did an audio-only presentation.

The graduate students and post-doctoral fellows in my laboratory took bets after watching infants in the DVD condition – who stared at the monitor and even crawled up to it. Some touched it. They bet that the DVD would win over "live" because the DVD was so beautifully clear. There were fewer distractions and babies seemed riveted by the action on the screen.

But the results of brain and behavioral tests showed that only infants who experienced native Mandarin speakers "live" showed evidence of having learned. Those who watched the same native speakers on DVD, or heard them through loudspeakers, performed no differently on tests of Mandarin sounds than infants in a control group who heard only English from American native speakers in otherwise identical sessions. Learning was phenomenal: "live" infants matched Taiwanese infants who had ten months experience listening to the language.

The result was a huge surprise. It challenged existing theory, has affected educational practices, and jolted the baby DVD industry.

What led us to do the experiment? What were the theories and predictions at the time? And how did the finding lead me to a new hypothesis, the "social gating" hypothesis?

Two highly polarized theories shape the field of language acquisition, each elegantly argued by giants in the field. MIT professor Noam Chomsky favors a nativist position, positing a Language Acquisition Device (LAD) that triggers parameters of innate universal phonology and grammar through language input. Brown University professor Peter Eimas fleshed out this view, arguing that innate "phonetic feature detectors," encompassing the sounds of all languages, atrophied when the language infants heard did not include a particular phonetic feature.

Al Liberman of Haskins' Laboratories at Yale argued that "speech is special" – that brain systems were "modularized" such that other cognitive processes could not influence them.

The alternative view, expressed by Harvard professor B. F. Skinner, held that language required only operant conditioning and reinforcement to reward and eventually shape the behavior of children as they uttered words. Infants were, in effect, "blank slates," waiting for parental tutoring. The nativist and learning positions could not have been more disparate.

However, as data began to pour in from experimental studies on infants, a new view beyond the two alternatives appeared to be required.

A few of these findings were that: (a) infants were born with the capacity to discriminate all the phonetic contrasts of all languages, even if they had never heard these sounds – they were "citizens of the world," a feat not accomplished by their "language-bound" parents; (b) a "sensitive period" between approximately eight and ten months of age was identified, during which a dramatic change occurred in infants' perception of speech. During this period, infants' performance on native sounds increased significantly, while their ability to discriminate non-native contrasts declined. I had earlier shown that non-human animals show enhanced discrimination at the locations of phonetic "boundaries" between two categories, which suggested evolutionary continuity between complex auditory processing in animals and humans, and underscored the idea that infants' initial capacities did not necessitate the existence of phonetic feature detectors at birth.

The learning position took a significant step forward with the discovery that infants were capable of *implicit* learning – different from explicit learning, and distinct from operant conditioning à la Skinner. This gave infants computational strategies that helped them learn simply by listening to people talk. In effect, infants were shown to "take statistics" as they listened to us speak.

In laboratory tests, infants from an early age were shown to be sensitive to the distributional frequencies of phonetic units when exposed to a series of eight stimuli from a continuum. For example, in a series of stimuli ranging from the syllable /ra/ to the syllable /la/, infants exposed to a higher proportion of the endpoint stimuli became better at discriminating /ra/ from /la/. On the other hand, infants who heard a higher proportion of the intermediate stimuli became worse at discriminating /ra/ from /la/. This meant that infants in Japan, who hear intermediate sounds appropriate for Japanese, should get poorer during the sensitive period at discriminating /ra/ from /la/ – and, indeed, experiments show that they do. This kind of implicit "statistical" learning was occurring at an age well

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before parents were even aware that their children were learning, before parents were "rewarding" infants for learning. This kind of learning happened automatically.

This formed the backdrop for my design of the language exposure experiment. My initial goal was to test whether infants could learn the statistical properties of a new language if exposed to that language for the first time during the sensitive period. Infants hear their native language from birth, but the transition in phonetic perception does not occur until about eight months of age – why? Did it mean that infants needed eight months to build up statistical distributions of the sounds they heard in ambient language? If so, then twelve sessions of exposure to a new language, with its novel sounds and statistics, would not be sufficient to learn the sounds of Mandarin Chinese. But if twelve sessions – less than five hours – was sufficient, then something else was going on. Performance of infants in the control group ensured that simply coming to the laboratory for twelve sessions of listening to English did nothing to improve infants' Mandarin skills.

As the exposure experiment got underway, I began to notice how happy infants in the "live" group were as they sat in the waiting room prior to the experiment. They'd watch the door, smiling when one of the Mandarin tutors walked in. They were clearly happy campers. Control infants looked typical, but not exuberant. I began to wonder about the "social" component. What role was social interaction playing? The classic "statistical learning" experiments did not involve social interaction – infants hear audio tokens of speech, and they learn without the presence of a human being. But our experiment required learning from a complex, live, natural language interaction. Was there something about this natural social setting, with all its complexity, that actually enhanced language learning?

We tested this idea via the DVD and audio-only conditions. And voila! We had the answer – the human being was *essential* for learning. No learning occurred in the absence of a person.

This discovery gave rise to my "social gating" hypothesis: the idea that social interaction "gates" language learning. The finding caused many to suggest experiments and to offer explanations. The *contingencies* involved in natural interaction, something that's missing from a TV presentation, were often mentioned. The fact that infants could learn from following the gaze of the tutor, easier in the live as opposed to the DVD sessions, also came up often. Biologists offered the thought that pheromones, sensed only during "live" sessions, could be responsible. It was deeply satisfying to have been the catalyst for so much talk about infants' social brains!

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The hypotheses I offered positioned the "social gating" hypothesis as an advantage infants accrued from two non-mutually exclusive sources: (1) enhanced *motivation* derived by face-to-face human interaction, and (2) enhanced *information* derived by tracking the tutor's eye movements and following their gaze. In further experiments (not yet published) we have demonstrated that both these factors play a significant role in infants' learning. We are using interactive screens, "social" robots, and even testing infant learning solo versus in pairs to test our hypotheses. We're having fun!

We are also exploring the brain basis of the effect in several experiments. One published result is intriguing: Using MEG brain imaging technology, we demonstrated that when seven- and eleven-month-old infants hear speech (but not non-speech), the brain's motor systems are activated – Broca's area and the cerebellum respond within milliseconds of the activation in auditory sensory cortex. This activation occurs for both native and non-native speech before the sensitive period. After the sensitive period, non-native speech shows even greater motor activation. Taking a cue from artificial intelligence, we argue that infants' brains, as they listen to us speak, are trying to "rehearse" the movements required to talk back. This is a social response, we believe, and we're following up on this idea with experiments that examine brain activation in response to DVD as opposed to "live" presentations while infants are in the MEG machine.

The discovery has affected educational systems as well as companies that develop videos aimed to teach languages to young infants. It has impacted developmental theories linking cognitive and social development and is leading to a new view of language acquisition.

I still do not fully understand how the social brain "gates" language learning, or indeed if this is the correct theoretical position. But stay tuned, and join me if you are so inclined. There are future discoveries to be made.

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