

*In the Beginning: On the Genetic and  
Environmental Factors That Make Early  
Language Acquisition Possible*

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**1. Introduction**

My journey towards understanding the biological foundations of human language has crossed a diverse path, involving (a) comparative analyses of two different species – apes and humans; (b) comparative analyses of languages in two different modalities – signed and spoken; and (c) comparative analyses of the structure, grammar and acquisition of different signed languages. In trying to understand the biological foundations of a capacity, it is first necessary to determine the extent to which the capacity is species-specific. Hence, while still a college undergraduate, I moved into a large mansion on the Hudson Palisades in New York with an infant, West-African male chimpanzee, named “Nim Chimpsky.” This animal was part of a research project at Columbia University in which I attempted to raise the chimp like a child and to teach him signed language. Our research question concerned whether aspects of human language were species-specific or whether human language was entirely learnable (and/or teachable) from environmental input (Terrace, Petitto, Sanders and Bever 1979).

Although there is much controversy surrounding the ape language research, what has remained surprisingly uncontroversial about all of the ape language studies to date is this: all chimpanzees fail to master key aspects of human language structure, even when you bypass their inability to produce speech sounds by exposing them to other types of linguistic input, for example, natural signed languages. In other words, despite the chimpanzees’ general communicative and cognitive abilities, their linguistic abilities do not equal humans ability with language, whether signed or spoken. This fact suggested to me the hypothesis that humans possessed something at birth in addition to the mechanisms for producing and perceiving speech sounds per se. Indeed, whatever this elusive “something” was, I knew that attempts to understand it would

provide the key to what distinguishes human language and thought from the communication of other animals.

## 2. Research Questions

Since working with Nim, my research has been motivated by basic questions in Cognitive Science and Cognitive Neuroscience concerning the neural architecture underlying language acquisition in the developing brain. I ask two general questions of the infant and of the environment: (1) Are infants born with any innate mechanisms that aid them in the task of acquiring language? If so, are any of these mechanisms specifically sensitive to the unique organizational properties found only in natural language, or are general perceptual mechanisms sufficient for discerning the regularities of linguistic structure? (2) Are some aspects of the environmental input more critical than others in order to begin and to maintain the language acquisition process?

Most contemporary answers to the above questions have been based on the fundamental presupposition that the infant's emerging linguistic abilities are determined by the mechanisms underlying the production and perception of speech per se and/or mechanisms of general auditory perception. Given that only languages utilizing the speech modality are studied (i.e., spoken languages), it is in principle, *a priori*, impossible to find data that would do anything but support this hypothesis. Only by examining languages in another modality (i.e., signed languages) can we more fully determine the relative contribution of motor production and perception constraints – versus other factors (e.g., abstract regularities of linguistic structure) – to the time course and nature of early human language acquisition.

In my laboratory, I compare hearing and deaf infants' acquisition of spoken and signed languages. Because spoken and signed languages utilize different modalities (acoustic versus visual), and because the motor control of spoken and signed language articulators are subserved by different neural substrates in the brain, comparative analyses of these languages provide key insights into the specific neural architecture that determines early human language acquisition. Indeed, the existence of these languages permits us to tease apart which aspects of language acquisition reflect *modality-specific* properties of the language transmission and reception modality, and which aspects reflect *modality-free* properties of language representation in the developing brain.

Here I summarize two unique sets of findings about human language acquisition that have resulted from over a decade of research in my laboratory involving comparative analyses of very young children's acquisition of spoken and signed languages. One index of whether a capacity is under biological control is whether it develops

along a specific time course. Thus, in the first set of findings, I address the issue of the timing of linguistic milestones in early language acquisition as well as the critical environmental input factors that may (or may not) determine them.

Another index of whether a capacity is under biological control is whether (and, if yes, how) it is expressed in the face of fundamental change to the organism (the change may be either environmental and/or morphological). For example, in the case of language, I examine acquisition in the absence of sound, and acquisition in the face of radical morphological change to the language articulators and receptive mechanisms at the moment of birth. Thus, in the second set of findings, I ask whether infants are born with any innate mechanisms that aid them in the task of acquiring language by examining the presence or absence of structural homologies in the very early linguistic productions of sign- and speech-exposed infants. In the final pages of this chapter, I articulate a theory that best explains these facts of very early language acquisition, and I consider the impact of the present work on our understanding of the phylogeny of language in our species.

### 3. Research Findings

#### 3.1. *Timing Milestones: Identical Time Course in Speech and Sign Acquisition*

3.1.1. *Hearing children acquiring a spoken language and deaf children acquiring a signed language from birth.* To investigate whether certain aspects of the environmental input are more critical than others in early language acquisition, I conducted comparative analyses of monolingual hearing children acquiring spoken languages (English or French) and monolingual deaf children acquiring signed languages (American Sign Language, ASL, or Langue des Signes Québécoise, LSQ), ages 8 months through 4 years. (ASL and LSQ are distinct, naturally evolved signed languages. Neither ASL nor LSQ are based on the majority spoken languages used around them, English or French, respectively, and LSQ is grammatically distinct from the signed language used in France.)

The most striking finding is that deaf and hearing children acquire signed and spoken languages (respectively) in virtually identical ways, despite dramatic differences in the modalities. Deaf children acquiring signed languages from birth do so without any modification, loss or delay to the timing, sequence, content and maturational course associated with reaching all linguistic milestones observed in spoken language (Petitto 1984, 1986, 1987a, 1988, 1992; Petitto and Marentette 1990). Beginning at birth and continuing through age 5 and beyond, speaking and signing children exhibit the identical stages of language

acquisition, including the "syllabic babbling stage" (7 to 10 months approximately) as well as other developments in babbling, including variegated babbling (ages 10 to 12 months) and jargon babbling (ages 12 months and beyond), "first word stage" (11 to 18 months approximately), "first two-word stage" (18 to 22 months approximately), and systematic morphological and syntactic developments (for example, "over-regularizations," negation, question formation and so forth, 22 to 36 months approximately and beyond). Signing and speaking children also exhibit remarkably similar semantic, pragmatic, discourse as well as conceptual complexity. Indeed, analyses of signing children's social and conversational patterns of language use over time and the types of things that signing children "talk" about over time (i.e., the semantic and conceptual content, categories and referential scope of their "talk") have demonstrated unequivocally that their language acquisition follows the identical path as is observed in age-matched hearing children acquiring spoken language (Charron and Petitto 1991; Petitto 1992; Petitto and Charron 1988).

The present findings are very surprising.<sup>1</sup> Despite modality differences, deaf and hearing children acquiring signed and spoken languages (respectively) do so in highly similar ways, and they do so on an identical time course. The findings cast doubt on the hypothesis that the ability to hear and produce speech, *per se*, determines the time course and content of human language acquisition.

*3.1.2. Hearing children acquiring both a spoken and a signed language from birth.* To further determine whether speech was critical to language acquisition, a study of hearing children in "bilingual" and "bimodal" homes was conducted (their home environment provided both ASL and spoken English, or, LSQ and spoken French), ages 7 months through 24 months. For example, in these homes, one parent was deaf and used a signed language (e.g., ASL) and the other parent was hearing and spoke (e.g., English; the same holds for homes where both LSQ and spoken French were used). Thus, in these homes, each child was exposed to both a signed language and a spoken language from birth. The results revealed that these children achieved all linguistic milestones in both modalities at the same time (Petitto, Costopoulos and Stevens, in preparation).

The parallels observed in the children's achievement of signed and spoken language milestones cannot be overemphasized. In Petitto, Costopoulos and Stevens (in preparation), the children in all 4 families studied (2 families used ASL and English, and 2 used LSQ and French) achieved vocal and manual babbling, first words and first signs, first two words and first two signs, and so forth, either on the same day or

within one or two days of each other. Not only was the overall time course and content of their acquisition similar to that which has been observed in monolingual hearing and deaf children, but the children's patterns of language acquisition exhibited the same time course and content as is seen in other bilingual hearing children acquiring two spoken languages (e.g., spoken French and spoken English: Genesee 1987; Petitto and Marentette 1990; Petitto, Costopoulos and Stevens, in preparation).

These findings are inconsistent with the hypothesis that speech, per se, is critical to language acquisition. They challenge the related hypothesis that speech is uniquely suited to the human brain's maturational needs in language ontogeny, and they raise questions about our views of language phylogeny. If speech, per se, were neurologically privileged in ontogeny, bilingual and bimodal hearing children might be expected to attempt to glean every morsel of speech that they could get from their environment. Faced implicitly with a choice between speech and sign, the very young hearing infant in this context might be expected to turn away from the sign input, favouring instead the speech input, and thereby acquire signs later. This did not happen. Further, *some* vestige of the apparent phylogenetic preference for speech should have been seen in these infants – especially when faced with both types of input. That it was not observed raises questions about many of the presuppositions underlying theories of language phylogeny as well as its neurological roots in ontogeny, which will be discussed further below.

*3.1.3. Hearing children with no speech input from birth.* I recently began close investigations of a fascinating group of children. Children of the following sort have never before been studied; moreover, the findings from this first-time study have already proven to be theoretically powerful.

Like the children mentioned previously, these children are hearing. Like the hearing children above, they are acquiring two entirely different languages from birth. However, they differ from the bilingual, bimodal hearing children above in an important way. First, unlike the hearing children above, these hearing children are not being exposed to spoken language! In these families, both of the parents are profoundly deaf and both have made the radical decision not to expose their children to spoken language. To be clear, both deaf parents have chosen to expose their hearing children to language in only one modality from birth – specifically, to signs only (rather than to signs and speech). Second, each deaf parent uses a *different* signed language from the other parent. That is, in these families, one deaf parent uses ASL exclusively with the hearing child, and the other deaf parent uses LSQ exclusively

with the hearing child. Thus, the hearing children in this study are in a bilingual, *unimodal* (sign-only) environment, whereby they are acquiring two different signed languages from birth (but no spoken language).

A second group of hearing children is also under investigation. These hearing children are also not being exposed to spoken language. They, too, have profoundly deaf parents, but both parents use the same signed language (i.e., both parents use ASL, or, both parents use LSQ). Thus, these hearing children are in a monolingual, unimodal (sign-only) environment, whereby they are acquiring one signed language from birth (but no spoken language).

Why is this population so critical? These children are so interesting because they can hear but they are not being exposed to speech. As such, the children constitute an experiment in nature. Under other circumstances, it would not be possible to intentionally withhold spoken language from a normally hearing child. Thus, by investigating this population, it is possible to answer key questions about the mechanisms that underlie human language acquisition in an entirely novel way. If speech and sound are critical to the human language acquisition process, then these speech-deprived hearing children should demonstrate fundamentally atypical acquisition of signed language. This would be especially true if, for example, several prevailing views about very early language ontogeny are correct. In particular, numerous researchers have claimed that the motoric mechanisms for the production of speech, *determine* the time course, sequence and linguistic and semantic content of early language acquisition (e.g., Locke 1983; MacNeilage and Davis 1990; MacNeilage, Studdert-Kennedy and Lindblom 1985; Studdert-Kennedy 1991; Van der Stelt and Koopmans-van Bienum 1986; more below). On this view, without the guiding force of the development of speech production (and speech perception), the acquisition of signed language in these hearing children should exhibit timing and sequencing anomalies in addition to other peculiarities of a semantic and conceptual nature. Indeed, it could be argued that the bilingual, bimodal hearing children reported in section 3.1.2 above had similar patterns of spoken and signed language acquisition because sign was somehow yoked to speech. The present data address this important hypothesis.

The results revealed that the speech-deprived but sign-exposed hearing children achieved every linguistic milestone in signed language on the identical time course as has been observed for hearing children acquiring spoken language (as well as deaf children acquiring signed language – that is, manual babbling, first signs, first two-sign combinations and so forth). The things that these hearing children signed about (their semantic content, categories, referential scope), the



way that the children used signed language (its pragmatic and discourse structure) and the morphological and syntactic complexity of their signed utterances all mirrored that which is seen in children acquiring spoken language. Moreover, the hearing children acquiring two signed languages (but no speech) demonstrated the same overall linguistic developments as bilingual hearing children acquiring two spoken languages. For example, in the first-word stage they avoided the use of signs in each language that stood for the same lexical item (for example, if they produced the sign "cup" in ASL, they would avoid the use of the sign "cup" in LSQ; and there were other intriguing patterns of sign language "mixing"; see Petitto, Costopoulos, and Stevens, in preparation).

The above findings are surprising because normal language acquisition occurred in hearing children (i) without the use of auditory and speech perception mechanisms and (ii) without the use of the motoric mechanisms for the production of speech. Recall that most all accounts of early language acquisition root the infant's emerging linguistic abilities in the mechanisms for the production and perception of speech, *per se*, and/or mechanisms of general auditory perception.

Thus, the results of these studies provide dramatic support for the claim that speech and sound are not critical to the language acquisition process. Again, the children can hear but they are receiving no spoken language input – only sign. Moreover, our findings here fail to support the hypothesis that language acquisition proceeded normally in the bilingual, bimodal (speech- and sign-exposed) hearing children above, because the acquisition of sign was somehow yoked to the acquisition of speech. We see here that hearing children with no spoken language input nonetheless demonstrated entirely normal patterns of language acquisition, albeit in signed language.

*3.1.4. Summary of timing milestone studies.* We have seen that signed and spoken languages are acquired in virtually identical ways, despite the fact that the brain-based neural substrates are different for both (i) the motor control of speech and sign and (ii) the perception of speech and sign. The above findings, therefore, fundamentally challenge the hypothesis that speech and sound, *per se*, are critical to the process of language acquisition. The findings also provide support for the hypothesis that language is under maturational control and that unitary timing constraints determine the acquisition of all linguistic milestones, be they spoken or signed (cf. Lenneberg 1967).

Having established that the overall time course, sequence and content of signed and spoken language acquisition are highly similar, questions remain about just how deep the similarities are in acquisition at

the specific, structural level. I will now review a series of studies that addresses this issue in an attempt to shed new light on whether (and/or which) innate mechanisms aid very early language acquisition.

### ***3.2. Innate Mechanisms in Early Language Acquisition: Insights from Structural Homologies in Babbling across Different Modalities***

**3.2.1. Why Babbling?** A hallmark of human development is the regular onset of vocal babbling well before infants are able to utter recognizable words (Lenneberg 1967). One period of babbling, beginning around age 7 to 10 months, has been referred to as "syllabic vocal babbling." Syllabic vocal babbling is characterized by the infant's (a) use of a reduced subset of possible sounds (phonetic units) found in spoken languages (Locke 1983), (b) syllabic organization (well-formed consonant-vowel clusters: Oller and Eilers 1988) and, crucially, (c) use without apparent meaning or reference (Elbers 1982).

Why has infant babbling received so much scientific attention? In trying to understand the biological roots of human language, researchers have naturally sought to find its "beginning." The regular onset of babbling, as well as its systematic stages in the young infant (despite variation in rearing environments), have lead researchers to conclude that babbling is under maturational control and fundamentally linked to later language development. As such, infant babbling has been universally regarded as representing the "beginning" of human language acquisition (albeit, language production), and it has been the focus of intensive study and theorizing for many decades.

The very existence of babbling and its characteristic stages have been used by researchers to answer one of the most passionately sought after questions in human language ontogeny: How does language acquisition begin? To answer this question, researchers have used their findings about the nature of babbling to advance theories about the infant's brain at the onset of language acquisition. In particular, analyses of babbling have been used to support proposals regarding the underlying neural substrates that may determine (and drive) the maturational time course, sequence and referential content of all of early language acquisition.

As for the answer to the crucial question, the prevailing view about the origins of babbling, and, hence, the beginning of language acquisition in our species, has been that its very syllabic structure is *determined* by the development of the anatomy of the vocal tract and the neuroanatomical and neurophysiological mechanisms subserving the motor control of speech production (Locke 1983; MacNeilage and Davis 1990; MacNeilage, Studdert-Kennedy and Lindblom 1985; Studdert-Kennedy



1991; Van der Stelt and Koopmans-van Bienum 1986). The behaviour has been further used to argue that the human language capacity has a *unique link* to innate mechanisms for producing speech in ontogeny (Lieberman and Mattingly 1985, 1989). Crucially, it has also been used to argue that human language has been shaped by properties of speech in phylogeny (Lieberman 1984).

3.2.2. *Manual babbling in infants exposed to signed languages from birth.* In the course of conducting research on deaf infants' transition from pre-linguistic gesturing to first signs, I first discovered a class of manual behaviours that contained linguistically relevant units, was produced in entirely meaningless ways and was wholly distinct from all other manual activity during the "transition period" (9 to 12 months; Petitto 1984). Further analyses revealed that this class of manual activity constituted genuine instances of *manual babbling* (Petitto 1986, 1987a, 1987b).

An additional study was undertaken to understand better the underlying basis of this extraordinary behaviour. Physical and articulatory analyses (as in acoustic and phonetic analyses of sound) were conducted of all manual activity produced by ASL deaf and English hearing infants, ages 10, 12 and 14 months. The presence of hearing controls in this study was crucial, because it was necessary to determine whether the manual activity observed in deaf infants exposed to signed languages was similar or dissimilar to that which is observed in all infants, even those who are not exposed to signed languages. The findings, reported in Petitto and Marentette (1991), revealed unambiguously a discrete class of linguistically relevant, meaningless manual activity in ASL deaf infants that was structurally identical to the meaningless vocal babbling observed in hearing infants. Crucially, its structure was wholly distinct from all (hearing and deaf) infants' rhythmic manual motor activity as observed by Thelen (1991), Thelen and Ulrich (1991) and others. Further, its structure was wholly distinct from all (hearing and deaf) infants' communicative gestures (Petitto 1988, 1992). Most surprising of all, manual babbling possessed *syllabic organization*. It alone possessed signed-phonetic units and combinations of units that were structurally identical to the phonetic and syllabic organization known only to human language (signed or spoken). The findings raised the following question: Given that the same phonetic and syllabic babbling units are observed to occur across two radically different modalities, where does the common syllabic structure come from?

To understand this question better, a new study was conducted, using innovative technology in an entirely novel way (see Petitto, Ostry, Sergio and Levy, in preparation). Here analyses were conducted of all hearing and deaf infants' rhythmic, non-linguistic hand movements

(Thelen 1991). This manual activity was then compared to sign-exposed infants' rhythmic, opening-closing hand movements – movements that form the nucleus of the signed (and the spoken) syllable (indeed, this behaviour constituted the rhythmic nucleus of the manual activity identified as "syllabic manual babbling"; recall, also, that manual babbling forms were further constrained by the use of restricted sign-phonetic units that were used without apparent reference or meaning).

One goal of this new study was to address an alternative hypothesis from the one that I offer. The alternative hypothesis is as follows: manual babbling does not share syllabic organization with vocal babbling, but is, instead, more similar to all hearing and deaf infants' rhythmic motor activity. A further goal was to identify any universals of syllabic structure in the signed and spoken modalities, should they exist.<sup>2</sup> To conduct this study the powerful OPTOTRACK Computer Visual-Graphic Analysis System was used. The precise physical properties of all infants' manual activity were measured by placing tiny Light-Emitting Diodes (LEDs) on infants' hands and feet. The LEDs transmitted light impulses to cameras that, in turn, sent signals into the OPTOTRACK system. This information was then fed into computer software that we designed to provide information analogous to the spectrographic representation of speech, but adapted here for the *spectrographic representation of sign*. Thus, for the first time, we were able to obtain recordings of the timing, rate, path movement, velocity and analyses analogous to fundamental frequency ( $f_0$ ) for all infant hand activity, and to obtain sophisticated, 3-D graphic displays of each. This permitted us to empirically evaluate rhythmic, non-linguistic activity versus rhythmic, linguistic manual activity in infants in a way that (i) has never before been analyzed, and (ii) would be impossible to obtain through the analysis of videotapes alone. This system permitted us to perform the critical analyses of the study, including comparative analyses of the various classes of infant manual activity, deaf (and hearing control) adult-to-adult signing content and "sign prosody, and deaf (and hearing control) adult-to-infant signing content and "sign prosody" (see Petitto, Ostry, Sergio and Levy, in preparation).

Preliminary results reveal the following. (i) Systematic differences have been observed in the rhythmic timing, velocity and spectral frequencies of sign-exposed infants' manual babbling versus all infants' rhythmic hand activity (be they hearing or deaf). (2) Systematic similarities have been observed in the *timing* contours of infants' manual and vocal babbling. (3) Converging structures observed in infant and adult-to-infant signing and speaking productions suggest that all humans at birth may possess peak sensitivity to a rudimentary "timing envelope" – a rhythmic timing bundle in natural language prosody of

about 1.2 seconds, which is currently under intensive further investigation (see Petitto, Ostry, Sergio and Levy, in preparation, for a comprehensive discussion of the formal differences between syllabic manual babbling versus other rhythmic manual activities in infants). In addition, early handedness differences may distinguish manual babbling and linguistic productions from other motoric manual activity (Marentette, Girouard and Petitto 1990).

Homologous structural organization was observed in manual and vocal babbling, even though the neural substrates for manual articulation differ from the neural substrates for the articulation of speech. The above research confirms the hypothesis that speech is not critical to the production of babbling or to early language acquisition. This research fails to confirm the alternative hypothesis introduced above; manual babbling was found to be fundamentally different from hearing and deaf infants' other rhythmic motor activity.

Such studies have provided new insights into the relative contribution of the body's motor production constraints on the structure of the syllable in human language (be it spoken or signed), and they have provided a key window into the elementary units of perceptual sensitivity that may underlie very early language acquisition in our species. The implications of the studies above are returned to below, when I propose a theory of early language ontogeny.

*3.2.3. Cross-linguistic analyses of manual babbling in infants acquiring ASL and LSQ.* Cross-linguistic data have been collected on the entire range of manual activity of ASL and LSQ infants (ages 8 to 20 months; Petitto, in preparation, a). Like vocal babbling, these deaf infants first produced common sign-phonetic units – units that were not drawn from the particular sign-phonetic inventories of either ASL or LSQ. To be clear, infants exposed to signed languages from birth do not manually babble in any particular signed language. However, as is reported for vocal babbling (de Boyssen-Bardies and Vihman 1991), language-specific phonetic units are observed in these infants' manual babbling after or around 12 months. Thus, manual babbling occurs in more than one signed language, and the effects of experience with the target language observed in hearing infants are also observed in deaf infants.

*3.2.4. Hearing infants and manual babbling.* Surprisingly, bilingual and bimodal hearing infants exposed to signed and spoken languages produced two kinds of babbling – manual and vocal – and did so within the same developmental time period (Petitto, Costopoulos and Stevens, in preparation). Analyses of data from 8 infants (4 ASL and English; 4 LSQ and French) reveal that these infants demonstrate the

same "stages" of babbling in both modalities. The infants also demonstrate intriguing parallels in the overall types of phonological processes that they exhibit, regardless of the modality. Crucially, modality-specific differences regarding the specific phonological permutations that are possible and/or impossible in the respective modalities have also been observed, which are currently under investigation (Petitto, in preparation, b).

Taken together, the above findings indicate that babbling in early language ontogeny is not restricted to speech. Such cross-modal convergent findings point to the existence of a robust period of human language ontogeny during which infants produce the raw "form" of language, which may ultimately help them identify the inventory of units, and permissible combination of units, in their target language (cf. Jusczyk 1986). These findings also suggest that the syllable may be a natural unit of language distinctions (Bertoncini, Bijeljac-Babic, Blumstein and Mehler 1987; Bertoncini and Mehler 1979; Moon, Bever and Fifer 1992). My ongoing work is providing new insights into the origin of universal patterns in all infant babbling, as well as modality-specific differences. As such, these studies are providing a window into the relative contribution of (i) raw phonological constraints (i.e., linguistic, structural) versus (ii) motor production constraints in early phonological development.

#### 4. The Genetic Foundations of Language

The key issue for students of early brain development is not the fact that signed and spoken languages are acquired similarly, but to determine *why* this is so. How is it possible that languages in two radically different modalities can be acquired on a similar time course? Where does the capacity to produce common linguistic structures come from, given that the neural substrates controlling the production of signed and spoken language differ?

Crucially, how is it possible that the modality of language transmission and reception can be changed at birth – from speech to sign, or vice versa – without any delay or alteration to the nature and course of human language acquisition? How can the brain tolerate this radical change in the morphology of its expressive and receptive mechanisms for language, and what is the genetic basis for such stunning equipotentiality? Why are we justified in proposing that aspects of language acquisition are under genetic control in the face of such profound environmental influences (in particular, the ability to acquire language in one or the other modality, depending upon the specific environmental input)? Indeed, what do the present findings tell us about the role of genetics in language acquisition?

The present findings demonstrate that the brain at birth cannot be working under rigid genetic instruction to produce and receive language via the auditory, speech modality, *per se*. If this were the case, both the maturational time course and the nature of signed and spoken language acquisition should be different. By contrast, using a wide variety of techniques and subject populations, I have discovered that the acquisition of signed and spoken language is fundamentally similar.

The present findings suggest that the neural substrates that support the brain's capacity for language can be potentiated in multiple ways in the face of varying environmental pressures. The fact that the brain can tolerate variation in language transmission and reception, depending upon different environmental inputs, and still achieve the target behaviour, provides support for there being a strong *amodal* genetic component underlying language acquisition, rather than the reverse. That is, the genetic foundations of language are not at the level of modality, but at the level of abstract features of *language patterning*.

At birth, there appears to be a genetically determined sensitivity to specific aspects of language patterning – that is, a nascent sensitivity to specific aspects of the raw form or structure of language in the input (specified below). Crucially, there are multiple genetic pathways by which language acquisition can occur. Indeed, recent findings in molecular biology have demonstrated that a key feature of many genomes is that there is a large degree of genetic material that is duplicated. There are multiple pathways by which a human trait can be expressed (Tautz 1992; Wilkins 1993). As such, a growing number of biologists are abandoning simplistic arguments for a single gene locus of traits in favour of a multigenic loci of traits. In this multigenic view, metabolic and cellular networks provide a context for genetic expression (cf. Strohman 1994).

When the multigenic or epigenetic perspective is applied to the present findings, it can be seen that the acquisition of language is most probably achieved through the interaction of many genes and, therefore, it has the potential to be realized in different forms. While there is clearly a genetic component to language and the ability to acquire it, the particular realization of a given genetic component is subject to the modulation and expansion of both (1) other gene products in the brain and (2) environmental input. Thus, the human brain has the capacity to forge neurological connections for speech and for signing, because the articulators for both meet the necessary conditions for the expression and reception of natural language. Both types of articulators can be (i) perceived, (ii) segmented and (iii) produced (and both are inalienable parts of the human body). The maturation of the neurological circuitry of the brain occurs on a particular timetable that can be



seen through indices such as babbling, first words, first two-word combinations and the like.

Like the expression of other biological traits under genetic control, what we have witnessed here is a flexibility with regard to the modality of language transmission and/or reception, but a rigidity with regard to the underlying linguistic patterns or structures that are realized. Above I have articulated how it is possible for a capacity to be both under genetic control and still capable of morphological change. That is, I have addressed the issue of genetic flexibility in the face of environmental vagaries.

So what is genetically rigid or fixed? Here I suggest that a sensitivity to aspects of the specific distributional patterns found only in natural language is genetically determined and present at birth. We saw telltale indices of what these elementary structures may be when we observed the linguistic forms that were pushed out onto the hands and pushed out onto the tongue in early language ontogeny, especially manual and vocal babbling. Below I describe the particular mechanism by which genes and environment interact in early language acquisition. I propose that humans are born with a neural substrate that has peak threshold saliency to particular input patterns over others that are relevant to the structure of natural language.

## 5. A Theory of Early Language Ontogeny

### 5.1. *The Infant: A Pattern or Structure-Recognition Mechanism*

Signing infants' and speaking infants' ability to produce common structures (timing milestones and babbling studies) suggests that a common mechanism may be operating across signed and spoken language input. All infants may be born with a sensitivity to units of a particular size with particular distributional patterns in the input regarding aspects of the form or structure of language per se, irrespective of the modality of the input. The hypothesis being advanced here is that this sensitivity reflects the existence of structural constraints at birth – a “structure-recognition mechanism” – by which particular distributional patterns in the input have peak threshold saliency over others. It is further hypothesized that the structure-recognition mechanism is specifically tuned to the unique stimulus characteristics of the input that correspond to two aspects of linguistically organized input – not modality – including (a) input structures that correspond to the rhythmic, timing and stress patterns common to natural language prosody and (b) input structures that correspond to the maximally contrasting, rhythmically alternating patterns common to the level of the syllable in natural language.



5.1.1. *The biological plausibility of a mechanism sensitive to particular input patterns over others.* Infants' sensitivity to aspects of language structure at birth may be possible due to a structure-sensitive mechanism similar to that which has been postulated for the recognition of faces (Gross 1992; Horn and Johnson 1989; Johnson and Morton 1991). For example, currently it is held there is no single "feature detector" neuron per se, for the detection of faces in the brain, but "patterned ensembles" of neurons (area IT in primates) that are selectively sensitive to particular spatial configurational patterns in the input and not others; and, the particular configurational patterns happen to correspond to just those frequency values that are found in faces (Gross 1992). Similarly, the infant's nascent sensitivity to aspects of language structure may reflect the presence of a neural substrate that is uniquely sensitive to the stimulus values specified in prosodic and syllabic structure. Specifically, the substrate may contain tuned neurons for contrasts and combination-sensitive neurons (Sussman 1984, 1989) which would make possible the infant's initial sensitivity to aspects of input that contain these particular values. Note that I am not proposing that the substrate, should it exist, has a particular language's structure written into it at birth. But it is a mechanism ready to differentially process input signals consisting of the language-specific values specified above (i.e., the rhythmical and temporal variables and maximally contrasting units that are unique to human language prosodic and sub-lexical organization). The nascent sensitivity to these patterns can serve as the foundation upon which knowledge of language is subsequently built.

5.1.2. *The role of parental input.* Without a doubt, parents' specifically linguistic and general affective interactions with their infants provide enormous clues to language structure. Parents impart structural information using multiple modalities (voice and intonation changes, facial expressions and lip movements etc.; Fernald et al. 1989), which is why it is probably best that the infant's sensitivity to structure is not tied to one modality. However, it would appear that we still need to posit some mechanism by which the infant is made capable of *attending to* particular input structures that will ultimately be relevant to their target language. In other words, there still must be some mechanism that provides the infant with the ability to perceive – in the first place – the adult's voice and/or face cues that are carrying information relevant to early language ontogeny. For example, adult prosodic cues can mark: (a) rhythmic, timing and stress variation that can regulate infant attention important for adult-infant "shared-regard," hence early reference; (b) conversational and interactional alternating patterns

important for achieving rudimentary discourse conventions; (c) phrase structure information critical to the acquisition of syntax (e.g., clausal, phrasal and word boundaries) and (d) phonetic segment information and its combinatorial possibilities in the target language and so forth (no specific ordering of importance is intended here, as prosodic variables can convey multiple types of information simultaneously). Indeed, by merely attributing to infants the innate sensitivity to the two features of natural language structure just described (prosodic and sub-lexical or syllabic), we provide them with the initial means to begin the language acquisition process well in advance of their having knowledge of the target language's grammar and its meanings. This is so because all of the information carried in prosody listed above (reference cues, conversational conventions, phrase structure, phonetic segments and so forth) are, in principle, derivable from giving the infant sensitivity to these two levels of natural language phonology. Thus, the infant's sensitivity to particular aspects of the input over others – posited here to be a "structure recognition mechanism" present at birth – may provide the infant with the ability (i) to attend to, (ii) to lay down in memory and, crucially, (iii) to establish a motor production loop with particular aspects of the abundant input that is bombarding its senses.

### *5.2. Critical Factors of the Environment*

The specific modality of the environmental input is not critical either to begin or to maintain human language acquisition. Speech, per se, is not critical to the human language acquisition process. It is the structure of the input that is the key, essential factor both to begin and to maintain the human language acquisition process. To be clear, linguistically structured input – and not modality – is the critical factor required to begin and maintain very early language acquisition.

### *5.3. Within Infant Interactions: Structure, Motor and General Perceptual Constraints*

When perceptual input enters, be it visual or auditory, it may shunt around the brain hitting its special processors (e.g., vision, the "structure-recognition mechanism" that I refer to above, or the way that the immune system uses both a rigid genetic program and environmental input to produce an immune response). The structure-recognition mechanism will be engaged if incoming perceptual information contains the specific structures above, thereby permitting (i) tacit decomposition of the input (which ultimately provides the infant with knowledge of the phonetic units and/or possible combinations; cf. Jusczyk

1986) and (ii) links with motor production that constrain the production of such structures. Because information about the input modality is preserved (Damasio, Damasio, Tranel and Brandt 1990; Maurer 1993; Meltzoff 1990), an infant can begin to produce babbling units in sign, if exposed to sign, babbling units in speech, if exposed to speech, and babbling units in speech and sign, if exposed to both modalities. Thus, language ontogeny begins through the complex interaction of three mechanisms: (1) general perceptual mechanism, (2) constraints on motor production and crucially, (3) specific structural constraints that are especially tuned to particular aspects of linguistic input. (For a discussion of why general perceptual, general motor, and/or general motor and general perceptual mechanisms alone are insufficient to account for early human language acquisition see Petitto 1993).

#### *5.4. Predictions of the Theory*

The above processes can and do occur across multiple modalities. Language acquisition is not restricted to speech. The prediction here is that as long as the input contains the appropriate patterns (or structures) relevant to natural language, input containing this structure should be acquired on the same time course, irrespective of the modality of the input. The findings from the above studies demonstrated this pattern.

### **6. Language Phylogeny**

The very existence of (non-invented) naturally evolved signed languages, as well as the apparent effortless way in which they are acquired in ontogeny, present us with the following phylogenetic puzzle. If most of our species presently speaks – presumably due to phylogenetic processes – where does the ontogenetic capacity to acquire signed languages come from? To be sure, it is not advisable to go from behavioural facts of language ontogeny to theories of language phylogeny. Nonetheless, I provide preliminary speculations here because current hypotheses about language phylogeny have ignored the facts of signed language acquisition. For example, the fact that there is an equipotentiality of the signed and spoken modalities to receive and produce language in ontogeny has been clearly established but it is routinely ignored. Although it is desirable that accounts of language ontogeny be compatible with hypotheses about language phylogeny, it is utterly essential that hypotheses about language phylogeny be wholly consistent with the facts of language ontogeny. Here I provide extremely preliminary speculations about language phylogeny that, at the very least, are consistent with the facts from early signed and spoken language acquisition.

**6.1. *Why Is There Not a Preference for Speech in Language Ontogeny? What Characteristics of Language Have Been Selected for?***

It has been argued that the mechanisms for producing speech were selected for first, and then came language (i.e., "syntax"; see Lieberman 1984, 1991). A clear implication, then, is that our brains are neurologically "wired" for speech per se which, in turn, makes human language acquisition possible. On this view, when large numbers of deaf people coalesced in a stable way to form communities of signers, these signed languages were developed within the already existing signaling system geared for speech. Thus, according to this view, it is not surprising that speech and signed languages share common linguistic structures.

There are at least three important problems with this type of hypothesis. First, this account does not explain *how* such common structures are possible in signed and spoken language acquisition, given that the neural substrates underlying the motor control of the speech and sign articulatory apparatus are distinct. Second, the clear prediction consistent with this hypothesis is that speech should be far better fitted to language structure, expression and reception than signed languages. However, all psycholinguistic and neurolinguistic studies to date on the structure, grammars and acquisition of signed languages indicate that this is not the case. Third, a further prediction here is that bilingual and/or bimodal children should show some preference for speech, which is not observed.

In an alternative view, the evolution of language has not occurred exclusively in terms of the mechanisms for the motor production of speech per se (as is asserted above). In this view, *some form of symbolic capacity* may have existed prior to, and/or at the same time as, the ability to express it was evolving. Internal factors, for example, deriving from an awareness of self and/or consciousness, the symbol, as in X "stands for" Y and so forth, could have exerted pressure on the means for expressing its contents.

The hands and the tongue provided the brain with two optimal candidates for language expression and reception. Both satisfy the criteria for serving as the articulators for natural language; both can be (1) produced, (2) segmented and (3) perceived. Because of certain signalling advantages common to sound (its speed and rate of transmission and reception; use of speech frees up the hands for other activities and so forth), speech was preferred. Whatever the elusive advantage is, it provided speech with an edge, and, hence, most of us speak.

Crucially, it does not follow from the fact that most of us speak that speech per se was exclusively selected for in the phylogeny of language. Because speech proved more useful than sign it has been

tempting to conclude that speech has been selected for. However, the present data are inconsistent with this hypothesis. The fact that all of us have the capacity to sign in ontogeny is telling in this regard. Why is there no preference observed for speech in ontogeny? One reason may be that selection has occurred for "Language" – that is, aspects of its abstract structure and semantic and/or conceptual underpinnings – but it has not yet fully selected for the expressive modality, although it has come very close regarding existing speech perception and production mechanisms.<sup>3</sup> Another reason, one that I favour, is that to solve the problem of differentiating between speech-linguistic versus speech-non-linguistic information being received and expressed in the same auditory modality, the brain was pushed to some other level of language abstraction.<sup>4</sup> Perhaps an abstract structure-recognition mechanism evolved due to the problem of separating out linguistic speech from non-linguistic sounds – a mechanism that does not itself have motor specifications in it, although it is linked with them. A spinoff of the existence of this structure-recognition mechanism would be that humans could generate alternative pathways for perceiving and producing language because they already have a structure-recognition mechanism that is not tied to a particular modality. This may be how it is possible that signed languages exist. And, this may be why we see no preference for speech over signed input in language ontogeny, because (i) both demonstrate the requisite structures of natural language; (ii) both can be just as easily acquired and used and (iii) both can be just as easily used as a vehicle for the representation and expression of thought.

It may be that certain pressures – for example, the need to separate linguistic speech from non-linguistic vocalizations (as well as speech input from non-linguistic auditory input) – rendered a solution to these pressures by pulling away from a strictly *speech-motor representation* of language to a new, more abstract *structure-motor* representation.

## 7. Summary and Conclusions

In this chapter, I have tried to articulate a plausible theory of language acquisition, taking into account what is currently known about genetically endowed systems, as well as the facts of early epigenesis. When the neural substrates underlying language acquisition are seen as having a great deal of redundancy built into them, then the system is protected against both environmental and physiological changes that could potentially occur. It is not the case that if the preferred pathway is unavailable, then another pathway will kick in. Rather, other pathways will develop if one set of genetic or environmental inputs is not present. This view predicts that there will be no delay in the acquisition of language if the hearing pathway is unavailable, or if speech input is

not presented to the hearing pathway. Having multiple genes and pathways available for the expression of fundamental capacities in an organism is common in biology. In this important way, the human language capacity is entirely consistent with the way other biological systems work, and I have articulated precisely which components of our capacity for language may be under genetic control.

I have argued here for the existence of a structure-recognition mechanism in newborns that is uniquely sensitive to particular aspects of natural language structure in the input (i.e., prosodic and sub-lexical or syllabic aspects), not to modality. I outlined how this mechanism crucially works in conjunction with general motor production and general perceptual constraints in early language ontogeny. I advanced the hypothesis that speech input per se is not critical to early language ontogeny. Instead, linguistically relevant structures encoded within the input are key. I further demonstrated that there is an equipotentiality of the modalities (spoken or signed) to receive and produce natural language from birth. As long as the input contains the specific distributional patterns of natural language structure, infants will begin to acquire it, irrespective of the modality of the input. Further, I have suggested ways in which the course of early signed language acquisition, as well as the very existence of human signed languages, can be suggestive regarding our understanding of human language phylogeny. These conclusions have radical implications for how we construe the genetic foundations of language, and suggest new ways of theorizing about the genetic and environmental factors that together create the neurological foundations of language.

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### Notes

- 1 Previously, researchers posited that signed languages should be acquired in a *different* way than spoken languages. To be sure, several researchers have claimed that there is a "sign advantage" (Meier and Newport 1991). That is, deaf children exposed to signed languages are said to produce their first signs prior to the time when hearing children produce their first words. These researchers have further posited that signed languages are acquired earlier than spoken languages.



- Most of the claims regarding the earlier onset of first signs over first words stem from one group of researchers (e.g., Bonvillian, Orlansky and Novack 1983; Bonvillian Orlansky, Novack and Folven 1983; Folven and Bonvillian 1991). The subjects in their studies were reported to have produced their "first sign" at a mean age of 8.2 months (a date that differs from hearing children's first words, which occur at approximately 11 months). However, in their studies, "first signs" were *not* required to be used referentially (that is, they were not required to be used in any meaningful way). Instead, if the children's productions contained "recognizable" adult phonetic forms, they were attributed sign (= lexical) status, even if the productions were not used "referentially." Equally damaging is the fact that the primary data used to make the "first sign" attributions were not based on actual samples of the young children signing. Instead, the attributions were based on analyses of the mothers' productions, and, worse, on her memory of what her child had produced. However, like speaking mothers, signing mothers tend not to recall the actual form of the way children sign things, only what its communicative intent and content was (see Petitto 1992; see also Brown and Hanlon 1970). Given that the criteria established by Bonvillian et al. for the children's "first signs" did not have to have referential status, and given their reliance on data from the mother rather than from the child, it is not surprising that they attributed sign status to productions that were not lexical. What they actually measured is clear from the spoken language acquisition literature and from my own work: in spoken language, we see that hearing infants around ages 7 to 10 begin production of "syllabic babbling," whereupon they produce vocal sounds containing recognizable adult phonetic forms without any referential content, forms that are not used in any meaningful way. Thus, it would appear that Bonvillian et al. have mislabelled genuine instances of manual babbling in signing infants as being "first signs" (recall that their date for the age of first signs is 8.2 months – which is right in the middle of infants' manual babbling stage). To complicate matters further, Meier and Newport (1991) then based their theoretical arguments in support of the existence of a "sign advantage" largely on the claims of Bonvillian et al.
- 2 As is common and productive in scientific discourse, there is dissenting discussion about the sign-syllable. However, it has focused largely on whether "Hold" is analyzed as being part of the syllabic stem, along with "Movement," or whether it occurs with Movement due to a phonological process (e.g., Brentari 1989, 1990). Crucially, however, despite technical arguments of linguistic theory, there is no debate over the existence of syllabic organization within signed languages (for articles on the phonological, and/or syllabic, structure of signed language see also Coulter 1986; Liddell and Johnson 1989; Perlmutter 1989, 1991; Sandler 1986; Stokoe 1960).
  - 3 I thank Kevin Dunbar for first suggesting this possibility to me.
  - 4 I thank Leda Cosmides who first made this connection after I had argued that there appeared to be a common, higher level of abstraction that characterizes the observed commonalities between signed and spoken language structure.

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