# Developmental Neurocognition: Speech and Face Processing in the First Year of Life

Edited by

Bénédicte de Boysson-Bardies,
Scania de Schonen, Peter Jusczyk,
Peter McNeilage and John Morton

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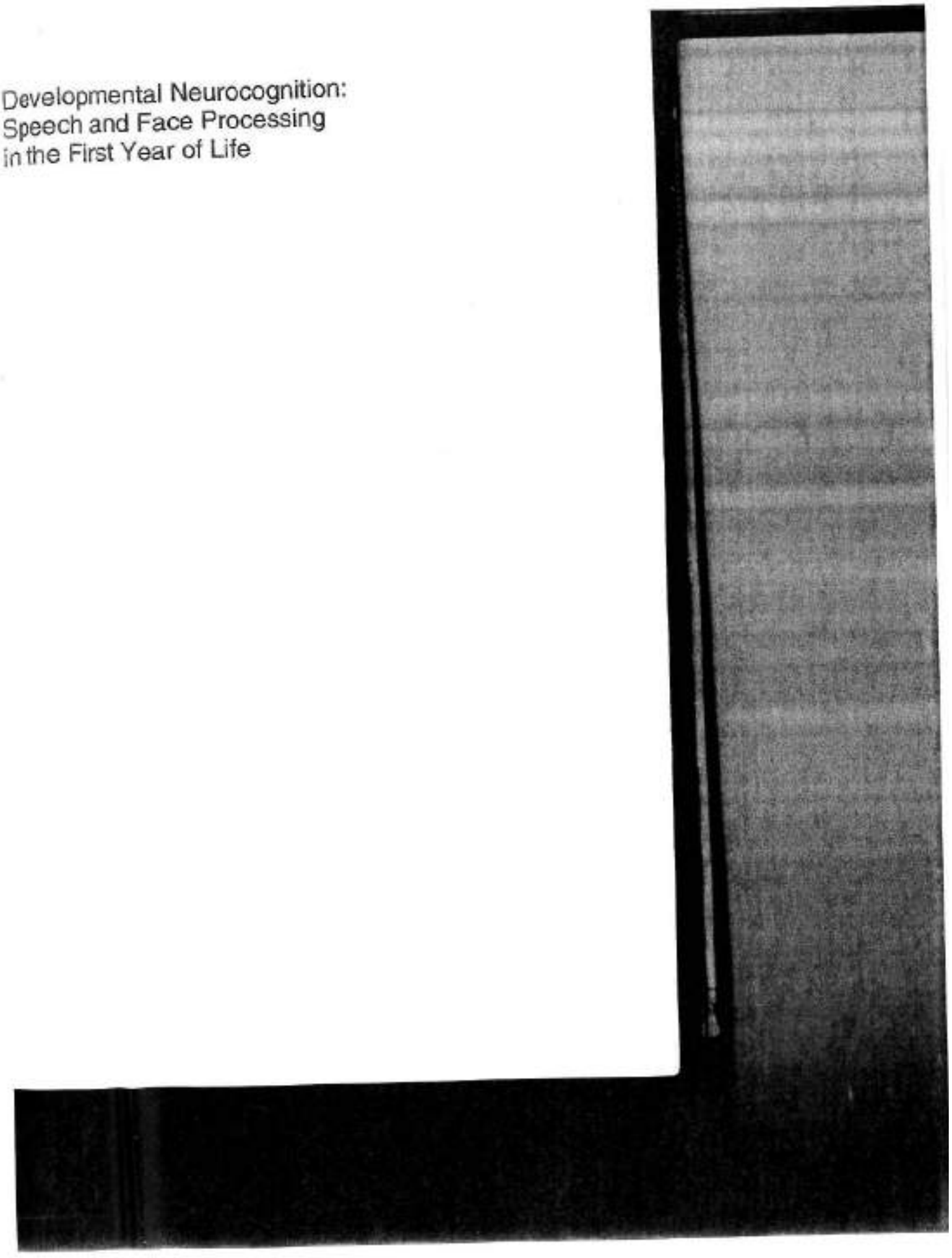

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# ON THE ONTOGENETIC REQUIREMENTS FOR EARLY LANGUAGE ACQUISITION

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ABSTRACT. A key challenge in the study of early language ontogeny is to discover when and how human language acquisition begins. Here, I attempt to move beyond dichotomous nature-nurture explanations of this process in my pursuit of the mechanisms underlying early language ontogeny. I do this by examining early language acquisition from a different perspective: I compare and contrast spoken and signed language acquisition. Then, based on the four sets of findings summarized below, I formulate a testable theory about the mechanisms that underlie early language acquisition, as well as the specific features of the environmental input, that together make possible human language acquisition. I further propose a new way to construe language ontogeny. Specifically, I advance the hypothesis that speech, per se, is not critical to language acquisition. Instead, I propose that the specific distributional patterns, or structures, encoded in the input - not the specific modality - are the critical input features necessary to enable very early acquisition to begin and to be maintained in our species from birth. A discussion relating the present findings to hypotheses about language phylogeny is also provided.

## 1. Introduction

My research is concerned with uncovering the biological mechanisms and environmental factors that together determine the course of early human language acquisition. 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 them specifically sensitive to the unique organizational properties found only in natural language, or are these general perceptual mechanisms which may be 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?



B. de Boysson-Bardies et al. (eds.),
*Developmental Neurocognition: Speech and Face Processing in the First Year of Life* 365–383.

As reviewed below, several theories of very early language ontogeny are based on the hypothesis 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 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 research, 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 critical insights into the effect of modality on the structure and acquisition of language. Indeed, the existence of these languages permits us to tease apart which aspects of language acquisition reflect modality-specific properties of the language transmission/reception mode, and which aspects reflect modality-free properties of language representation.

Below, I first summarize several unique 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. A discussion of the theory that best explains the facts of very early language acquisition follows.

## 2. Research Findings

### 2.1. DISCOVERY OF AN IDENTICAL TIME COURSE IN SPEECH AND SIGN ACQUISITION.

*2.1.1. Unilingual Children.* To investigate whether certain aspects of the environmental input are more critical than others in early language acquisition, I conducted comparative analyses of unilingual hearing children acquiring spoken languages (English or French) and unilingual deaf children acquiring signed languages (American Sign Language, ASL, or Langue des Signes Québécoise, LSQ)[1], ages 8 months through 4 years. The most striking finding is that 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 (e.g., Petitto, 1984, 1986, 1987a, 1988, 1992; Petitto & 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 (7-10 months, approx., as well as other developments in babbling, including variegated and jargon babbling, ages 10-12 months and beyond), first word stage (12-18 months, approx.), first two-word stage (18-22 months, approx.), morpho
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months, approx.), morphological and syntactic developments (22-36 months, approx., and beyond). Signing and speaking children also exhibit remarkably similar semantic, pragmatic, discourse, and conceptual complexity (Charron & Petitto, 1991; Petitto & Charron, 1988).

Such findings are surprising. Previously, some researchers have posited that signed languages may be acquired earlier than spoken languages due to (a) maturational rate differences in the visual versus auditory cortex and to differences in the motor control of the limb versus oral-vocal tract (Bonvillian et al., 1983a&b; Folven & Bonvillian, 1991; Meier & Newport, 1990), (b) the larger size of manual gestures, which permits more opportunity for parental molding of infant hands (Bonvillian et al., 1983a), and (c) the occurrence of non-arbitrary, iconic signs in signed languages (e.g., Brown, 1979). Indeed, some researchers have further claimed that first signs are acquired earlier than first words, although they agree that all other milestones are the same in both modalities (Bonvillian et al., 1983a&b, Folven & Bonvillian, 1991; Meier & Newport, 1990)[2]. My findings do not confirm these hypotheses; see Footnote 2. They also 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.

*2.1.2. Bilingual, Bimodal Hearing Children.* To further determine whether speech was critical to language acquisition, a study of *hearing* children in "bilingual", "bimodal" homes were conducted (ASL/English; LSQ/French), ages 7 through 24 months. These hearing children were exposed to signed and spoken languages from birth. The results revealed that they achieved all linguistic milestones in both modalities at the same time (vocal and manual babbling, first words and first signs, first two words and first two signs, etc.), and on the same time course as do other children acquiring two spoken languages (e.g., Genesee, 1987; see Petitto & Marentette, 1990; Petitto, Costopoulos, & Stevens, in preparation). These findings are inconsistent with the hypothesis that speech, per se, is critical to language acquisition, and they challenge the related hypothesis that speech is uniquely suited to the human brain's maturational needs in language ontogeny. If speech, per se, were "privileged", bilingual/bimodal hearing children might be expected to attempt to glean every morsel of speech that they could get from their environment, favoring instead the speech input, and thereby acquire signs

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2 - Most all of the claims regarding the earlier onset of first signs over first words stem from one group of researchers (e.g., Bonvillian et al., 1983a&b; Folven & Bonvillian, 1991). In their studies, Bonvillian et al., provide two dates for the occurrence of "first signs" (though much of the field tends only to cite the first date): "First signs" are said to appear at 8.2 months, if the productions contained "recognizable" adult phonetic forms and if they were not required to be used "referentially." If, on the other hand, "signs" were required to be used "referentially", then a second date is provided as these infants' "first signs": that is, 12.6 months. However, as is standard in child language, infants' vocal productions within this period that contain phonetic units that are not used "referentially" are universally understood to be babbling. Thus, it would appear that these researchers have *mislabeled* and misattributed genuine instances of *manual babbling* in signing infants as being "first signs" (8.2 months; recall that the syllabic babbling stage is 7-10 months), with the typical age for first signs, in reality, being what they report as their second date for "first signs" (i.e., around 12 months; see also Petitto, 1988, for a discussion of other methodological considerations associated with this research, including the overattribution of linguistic "sign" status to infants' non-linguistic communicative gestures). To compound the problem, Meier & Newport (1990), then based their arguments in support of the existence of a "sign advantage" largely on Bonvillian et al.s' claims.

later. This was not observed. Taken together, these findings support an alternative hypothesis that speech, per se, is not critical to the language acquisition process. 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 in both spoken and signed languages (cf. Lenneberg, 1967).

## 2.2 DISCOVERY OF MANUAL BABBLING

*2.2.1. The Phenomenon.* Despite differences between spoken and signed language articulators, infants acquiring these languages produce fundamentally similar linguistic structures, with the discovery of infant manual babbling providing a clear window into this phenomenon. In the course of conducting research on signing infants' transition from pre-linguistic gesturing to first signs, I performed extremely close analyses of the "physical" variables (analogous to the "acoustic" level of sound analyses), as well as "articulatory" variables (analogous to "phonetic" level) of *all manual activity* produced by ASL deaf infant girls of ASL deaf parents (6-28 months). To my surprise, I observed a class of manual activity that was unlike anything else that I had observed: These manual behaviors contained linguistically-relevant units, but were produced in entirely meaningless ways, and they were wholly distinct from all other manual activity during the "transition period" (9-12 months) - that is, general motor activity, communicative gestures, proto-signs, and signs. Subsequent analyses revealed that this class of manual activity constituted genuine instances of *manual babbling*. Indeed, the behaviors abided by the identical timing, patterning, structure, and use of the vocal behavior in hearing infants that is universally identified as "babbling", and they progressed through the same stages as vocal babbling (e.g., reduplicative/syllabic, variegated, jargon babbling). This discovery was first presented with other analyses in Petitto (1984, 1986, 1987a). Because of the theoretical ramifications of this finding, two separate pilot studies were conducted of (a) 1 ASL deaf boy (4-20 months), and (b) 2 LSQ deaf boys (8-20 months), both of which independently confirmed the above findings. Then, cross-linguistic analyses were conducted of the manual babbling of *ASL* and *LSQ* infants, and all of these analyses were presented in Petitto (1987b).

The discovery of manual babbling was very surprising and very controversial. A hallmark of human development is the regular onset of vocal babbling well before infants are able to utter recognizable words (e.g., Lenneberg, 1967). All previous theorizing about the origin of babbling in hearing infants held that the syllabic *structure* of infants' vocal babbling was determined by the development of the anatomy of the vocal tract and the neuroanatomical and neurophysiological mechanisms subserving the motor control of speech production (e.g., Locke, 1983; MacNeilage & Davis, 1990; MacNeilage, Studdert-Kennedy & Lindblom, 1985; Studdert-Kennedy, 1991; Van der Stelt et al., 1986).

In 1990, a major study was undertaken to understand better the underlying basis of this extraordinary behavior. 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, 14 months. The introduction of hearing controls to this study was crucial, because it was necessary to determine whether the manual activity observed in deaf infants exposed to signed languages was similar/dissimilar to that which is observed in all infants, even those who are not exposed to signed languages. The findings,

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reported Petitto & 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. Indeed, its structure was wholly distinct from all infants' (i) motor manual activity (Thelen, 1991; Thelen & Ulrich, 1991) and their (ii) 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 babbling units (i.e., phonetic and syllabic) are observed to occur across two radically different modalities, *where does the common syllabic structure come from?*

To address this question, comparative studies of all infants' (a) rhythmic, non-linguistic hand/body movements (e.g., Thelen, 1991) versus sign-exposed infants' (b) rhythmic, open-closing movements that form the nucleus of signed (and spoken) syllabic babbling, were conducted to address an alternative hypothesis from the one that is offered here (i.e., manual babbling does not share syllabic organization with vocal babbling, but is, instead, more similar to all hearing and deaf infants' rhythmic motor activity). Preliminary analyses - using computer-graphic analyses analogous to the spectrographic representations of speech, but built for signed languages - reveal that "syllabic manual babbling" versus all infants' rhythmic, non-linguistic hand/body movements (as in Thelen, 1991) are distinct. For example, (i) rhythmical patterning differences clearly differentiate both types of manual activity (Petitto, in preparation/a), (ii) early handedness differences distinguish manual babbling/linguistic productions from motoric manual activity (Marentette, Girouard, & Petitto, 1990); see Petitto (in preparation/a) for a comprehensive discussion of the formal differences between these two types of manual activities. New studies are currently being designed and begun to better understand the essential physical and articulatory properties that underlie all infants' repertory of manual activity in the first year of life, be it syllabic manual babbling or other motor hand/body activity (Petitto & Ostry, in progress) - studies that will provide new insights into the relative contribution of the body's motor production constraints on the structure of the syllable in human language (spoken or signed). Indeed, the implications of such studies (as well as the preliminary results) are returned to below, when I propose a theory of early language ontogeny.

2.2.2. *Cross-linguistic Analyses of Manual Babbling in ASL and LSQ.* Building upon my earlier cross-linguistic pilot analyses (e.g., Petitto, 1987b), new data have been collected on the entire range of manual activity of ASL and LSQ infants (ages 8-20 months; Petitto, in preparation/b). 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 (e.g., Boysson-Bardies & Vihman 1991), language-specific phonetic units are observed in these infants' manual babbling after/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.

2.2.3. *Manual Babbling in Hearing Infants.* An entirely unexpected finding to emerge from the studies of timing milestones discussed above, was that bilingual/bimodal hearing infants exposed to signed & spoken languages produced two kinds of babbling - manual and vocal - within the same developmental window (Petitto & Marentette, 1990). Analyses of newly collected data from 8 infants (4 ASL/English; 4 LSO/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/impossible in the respective modalities have also been observed, which are currently under investigation (Petitto, in preparation/c).

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 (c.f. Jusczyk, 1986), and that the syllable may be a natural unit of language distinctions (e.g., Bertoncini, Bijeljac-Babic, Blumstein & Mehler, 1987; Bertoncini & Mehler, 1979; Moon, Bever & 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.

## 2.3. DISCOVERY OF A DISSOCIATION BETWEEN EARLY LANGUAGE AND GESTURE

I have found that all children (hearing and deaf) consistently differentiate linguistic versus non-linguistic, communicative gestures in early language acquisition. The dissociation between linguistic and non-linguistic information is particularly apparent in the study of signed language acquisition. Young deaf and hearing infants exposed to signed languages consistently differentiate between linguistic signs (identical to "words") and communicative gestures throughout development, even though (i) signs and gestures reside in a single modality, and (ii) some signs are "iconic" (pictorial) and/or "indexical", and, as such, they share formational and referential properties with some common gestures used in Western culture.

The study of pronoun acquisition provides a clear demonstration of the phenomenon (see especially, Petitto, 1987a). In spoken language acquisition, children begin to produce their first words around 12 months, but they do not begin producing personal pronouns (e.g., *"you"*, *"me"*) until around 18 months. Even then, some children exhibit pronoun reversal errors (saying *"you"* when they mean *"me"*). Both the lag between the onset of children's first words and pronouns and the reversal errors have been attributed to the complex linguistic and discourse roles that pronouns have in spoken languages: Pronouns "stand for" (symbolize) and refer to the grammatical categories (e.g., subject) in a sentence (i.e., pronouns are syntactically bound, co-referential parts of grammar), and in discourse their meanings "shift" with each change of speaker. For example, in a given conversation, I can use the pronoun "me" to refer to myself, but so can the person to whom I am speaking when she refers to herself.

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Contrary to the existence of pronouns with arbitrary forms (e.g., the *y+o+u* in spoken English), in ASL, linguistic pronouns are made by pointing: Pointing to self means "ME" and pointing to the addressee means "YOU". This situation provides a test of theories about the types of knowledge underlying language acquisition. First, all children - hearing and deaf - begin using the pointing gesture in rich and varied communicative ways around ages 9-12 months (e.g., they point to pick out objects and locations around them, they point at specific objects to get them, and, they point at people). Given that the linguistic pronoun for indicating person roles in ASL is formed by pointing, will deaf children differentiate linguistic and gestural communicating about self versus other? In particular, if children's acquisition of language is driven by a general cognitive and/or communicative competence to symbolize (e.g., Bates, Bretherton, Shore & McNew, 1983), then deaf children's knowledge and use of the early pointing gesture (ages 9-12 months) should facilitate their acquisition of linguistic pronouns relative to hearing children; pronouns in ASL may be learned earlier, at an accelerated rate, and, perhaps, in a relatively error-free manner.

This is not what happens. Like hearing children, deaf children begin using the pointing gesture in rich communicative ways at ages 9-12 months, including the use of points to objects, people, and so forth. At 12 months, all pointing to people stops, only to re-emerge around age 18 months, the precise period when hearing children first use pronouns. However, during the 12-18 period, all gestural communicative pointing (e.g., to objects, locations) continues in frequent, rich, and varied ways, and, also like hearing children, all reference to self and other is accomplished through the use of names (e.g., "Mommy"; "Daddy", "Eva"). Surprisingly, like hearing children, signing children produce reversal errors (e.g., pointing to other, as in "YOU", when they mean "ME", or vice versa), an error that could only have been made by ignoring the "transparent" (indexical) nature of the pointing gesture (see Petitto, 1987a, for an explanation of why the children make reversal errors).

Children's consistent differentiation between language and gesture supports the hypothesis that aspects of the structural and conceptual underpinnings of children's knowledge and use of language are distinct from their knowledge and use of gesture. Indeed, these findings do not support the hypothesis that knowledge of language is wholly derived from a general cognitive and/or communicative capacity to symbolize (e.g., Bates et al., 1983; c.f. Piaget, 1955).

## 2.4. DISCOVERY OF CONSTRAINTS ON LANGUAGE VERSUS GESTURE

Children's use of other, non-pointing manual gestures versus their use of early language also differ significantly. Young speaking and signing children's use of gestures is unconstrained relative to their use of early words or signs (see especially Petitto, 1992). I have observed that young hearing children acquiring words (around ages 12-18 months) produce even their earliest lexical items in constrained ways that correspond to different word types or "kinds". Said another way, words (signs) "refer" - be it to things in the world and/or to abstract concepts in our heads - and the things that words (signs) refer to typically form a conceptual group, known as a "kind" (e.g., Quine, 1977). Although this finding corroborates those reported for slightly older hearing children's acquisition of words (e.g., Huttenlocher & Smiley, 1987), other researchers have asserted that children's earliest lexical items are not so constrained (e.g., Nelson, 1988).

Additionally, I have observed that young children exposed to signed languages from birth also produce their earliest lexical items in constrained ways corresponding to "sign" (identical to "word") types or "kinds". Indeed, both signing and speaking children use their early lexical items in ways that suggest that their tacit hypotheses about the meanings of novel words/signs are constrained along such conceptual groupings or "kinds". Specifically, the range of referents over which children applied a particular word or sign formed particular "kinds" (e.g., kinds of objects, kinds of events, kinds of locations, kinds of possessions).

The above pattern is not true, however, of all children's use of gestures, including "symbolic gestures" (empty-handed gestures that "stand for" referents; e.g., "brushing" motions at the head for a hairbrush). Although occurring within the identical time period as words/signs, symbolic gestures are used both within and across word (sign) "kind" boundaries. For example, the same gesture will often be applied to a location, event, and object (in a broad associative manner), rather than to one particular category or kind.

Another difference noted between children's early lexicon and their use of gestures was that a symbolic gesture would appear only after children had the corresponding lexical item in comprehension and/or production (e.g., the "twist" gesture was observed only after children had the word/sign "open"), and the frequency of symbolic gestures was exceedingly low relative to children's early lexicon. These findings challenge the hypothesis that gestures precede language (e.g., Bruner, 1975), or that gestures have the same symbolic status as words (e.g., Bates et al., 1983). Indeed, symbolic gestures appeared to be parasitic on language rather than the reverse (see also Goldin-Meadow & Morford, 1989; McNeill, 1985).

The finding that gestures and language are used in distinct ways provides support for the hypothesis that distinct mechanisms for processing specifically-linguistic information may underlie aspects of language ontogeny (e.g., Chomsky, 1988; Gleitman, 1981; Pinker, 1984), and it provides key insights into the nature of linguistic and conceptual constraints underlying children's early lexicon that are being further investigated (Waxman & Petitto, in progress). That signing infants exhibit this gesture-sign dissociation is especially illuminating, because, again, both types of information reside in the same modality. What cues in the input, if any, aid these children in differentiating gesture from sign? The caretakers' gestural versus language input provides a tell-tale clue: First, both speaking and signing caretakers' gestures are not formed from a restricted set of units but are produced with forms that often vary from context to context. That is, they lack sub-lexical (phonetic, syllabic) organization. Second, caretakers further produce their gestures as concatenated lists - "lists" which (a) virtually never involve non-pointing "gesture+gesture" combinations (instead "point + gesture", and vice versa, is most common) and - regardless of the specific content of the combinations - (b) rarely, if ever, exceed two units long. Indeed, adult gestural input lacks the rhythmic, stress, and timing variables that are unique to natural language prosody, be it spoken or signed (they further lack a "syntax"). I hypothesize from these, and other, findings that infants possess a sensitivity both to sub-lexical and to prosodic variables (e.g., the fall-rise patterning, stress, and temporal cues that bind words/signs into clauses, phrases, and sentences), and that this sensitivity permitted them to distinguish gesture from signs (or words). This hypothesis figures prominently in the theory that I advance below.

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## 3. Summary of Research Findings

Several persistent findings emerge from the above studies: (i) Children exposed to either signed or spoken languages from birth produce all linguistic milestones on the same maturational time course (1 above). (ii) "Bilingual/bimodal" hearing children exposed to both signed and spoken languages from birth produce each linguistic milestones in both modalities at the same time, and no evidence for a preference for speech can be observed (1 above). (iii) Children exposed to signed and spoken languages from birth produce common structures found only in natural language, despite differences between the modalities (including differences in the neural substrates that control the motor production of sign versus speech; 2 above). (iv) Children's use of gestures versus their use of language is fundamentally distinct throughout development. Indeed, no change over time is observed in the internal complexity of all children's gestural productions; gestural complexity exhibits a flat 'M.L.U.' (e.g., Brown, 1973) - a fact that is not true of their blossoming linguistic productions (3 and 4 above).

The key issue for students of child language 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 structures come from, given that the common structures do not directly reflect the structural (production) constraints on the given modality (spoken or signed)? Why isn't there a preference for speech given that there is every indication that speech has been selected for? Answers to these questions will provide insights into the mechanisms that underlie early language acquisition in all humans.

## 4. A Theory of Early Language Ontogeny

The above findings do not support the hypothesis that speech-based production mechanisms, per se, wholly determine early language ontogeny. Because the neural substrates that control the motor production of speech versus sign differ, a prediction consistent with this hypothesis is that the time course and specific structures evidenced in spoken and signed language acquisition should differ. The present findings do not confirm this prediction.

I propose an alternative account regarding the origins and nature of early language ontogeny in all humans, which addresses the question of how the common time course and common structures are possible in early signed and spoken language acquisition.

### 4.1. THE INFANT: STRUCTURE-RECOGNITION MECHANISM

Signing and speaking infants' ability to produce common structures (babbling and time course studies), as well as their apparent sensitivity to sub-lexical and prosodic cues that bind units (gesture-language 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.

*4.1.1. Biological Plausibility.* The infant's "sensitivity" to aspects of language structure at birth may derive from a structure sensitive mechanism similar to that which has been postulated for the recognition of faces (e.g., Gross, 1992; Horn & Johnson, 1989; Johnson & Morton, 1991). For example, it is presently 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 (e.g., 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.

I do not find evidence that young infants' "sensitivity" to the two structures specified above is wholly learned in the traditional sense, although infants critically need linguistically-structured input in the environment for early linguistic structural analyses to be begun and to be maintained (i.e., for development to proceed). Further, the bilingual/bimodal infant's "sensitivity" to language structures do not appear to be biased towards which modality the input language structure must assume; in this sense only, the substrate, should it exist, may be "amodal". To review, it is hypothesized that infants may be born with a "sensitivity" to particular aspects of linguistically-organized input over others. This "sensitivity" may reflect the existence of a "structure-recognition mechanism" that in turn may be made up of a neural substrate that is uniquely tuned to the rhythmical and temporal patterning and the maximally contrastive units common to natural language phonology (especially prosodic and sub-lexical).

*4.1.2. Parental Input.* No doubt, parents' specifically-linguistic and general caring (affective) interactions with their infants provide enormous clues to language "structure". Indeed, parents impart "structural" information using multiple modalities (voice/intonation changes, facial/lip movements and expressions, etc.; e.g., Fernald et al., 1989; see also, Maurer; Locke; Muir; this volume), 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

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must be some mechanism that provides the infant with the ability to be able 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 "giving" infants the innate "sensitivity" to the two features of natural language structure specified above (prosodic, sub-lexical/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 (e.g., reference cues, conversational conventions, phrase structure, phonetic segments, etc.) 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 (more on production below).

## 4.2. 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. Instead, 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.

## 4.3. 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). 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/possible combinations; c.f., Jusczyk, 1986) and (ii) links with motor production that constrain the production of such structures. Because information about the input modality is preserved (e.g., Damasio, Damasio, Tranel & Brandt, 1990; Maurer, this volume; 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.

*4.3.1. Constraints on Motor Production: Are They Enough to Account for Early Language Ontogeny?* The link between the structure-recognition mechanism and constraints on motor production is vital - and this link *is* "special". That is, there appears to be a special, fine-tuned link between the *structure* of language and the *motor production* of these structures, rather than between language structure and the specific mechanisms for producing speech, per se. Insights into the existence of a special link between language structure and motor constraints derive from the discovery of syllabically organized manual babbling. Here, the motor features identified by MacNeilage & Davis (1990), and MacNeilage, Studdert-Kennedy & Lindblom (1985) for vocal babbling - i.e., the rhythmic, maximally opening (vowel) and maximally closing (consonant) alternations of the mandible - are also observed in infants exposed to signed languages - i.e., the rhythmic, "Movement/opening" and "Hold/closing" alternations of the hand(s). Indeed, the fundamental nucleus of the sign-syllable has a "Movement" (vowel-like) and "Hold" (consonant-like) contrasting alternation (e.g., Coulter, 1986; Fischer & Siple, 1990; Liddell, 1990; Liddell & Johnson, 1989; Perlmutter, 1989, 1991; Sandler, 1986)[3]. Thus, the behavioral facts observed in sign-exposed infants provide powerful support for MacNeilage et al.'s important proposal about the critical role of motor production constraints in early language ontogeny, particularly babbling. It also suggests, however, that these motor production constraints on babbling that MacNeilage and his colleagues note may not be governed exclusively by the mandible, per se. Instead, such constraints may reflect more fundamental, abstract motor production constraints *of the human body*, in relation to the structure of human language - motor constraints that are not tied to a particular modality and not tied exclusively to the mechanisms for producing speech (e.g., the mandible).

Although motor production constraints are clearly playing a critical role in language organization and acquisition, they are not sufficient to account for the common linguistic structures observed in spoken and signed acquisition. Support for this conclusion comes from studies of signed language acquisition where linguistic and non-linguistic (gestural) manual movements are in the same modality. First, infants exposed to signed languages do not utilize all possible, and all available, manual units present in their environmental input to produce in their manual babbling. Only select structures relevant to language organization but not gestures are produced by infants (more below). Second, all motoric manual activity in an infants manual inventory is not then used in their syllabic manual babbling. For example, the particular hand units (movements, orientations, locations) that are common to all infants' stereotypic and reflexive motoric manual movements (e.g., Thelen, 1991) are not all incorporated into infants' syllabic manual babbling. For example, in young infants' class of reflexive motor movements (i.e., not under infants' direct control), they can occasionally produce a "Y" hand (clenched fingers except for an extended thumb and pinkie),

3 - Dissenting discussion about the sign-syllable 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.

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*4.3.2. General Perceptual Mechanisms: Are They Enough to Account for Early Language Ontogeny?* Maybe, as many have claimed, general perception (in combination with some form of motor constraints) is enough to support early language acquisition. Here, again, the signed language data provide special insights. Infants exposed to signed languages appear to draw the units that they then incorporate into productive syllabic manual babbling (a behavior that is under their control) only from the linguistic samples around them, rather than from other communicative, intentional, and referential behavior such as parental gesturing. Why? Close analyses of the form and use of gestures as compared with the form and use of language (especially lexical forms) reveal differences between gesture and language that infants may be sensitive to. As stated above, gestures lack sub-lexical and prosodic organization found only in natural language; that sign-exposed infants appear to draw their babbling units only from linguistically organized input, rather than from other manual, non-linguistic input suggests that they are sensitive to these underlying organizational distinctions that differentiate both. As I propose above, (a) infants may be sensitive to specific aspects of the input relevant to natural language structure and (b) a mechanism for recognizing such specific structures in the input may be present at birth. Like other biologically-rooted systems, language constitutes a "fine-tuned" system: Language has particular structure and infants are initially sensitive to aspects of this structure. That gestural input lacks the sub-lexical/prosodic organization of natural language does not provide a sufficient explanation regarding the underlying mechanism by which infants can differentiate (perceive, attend to) linguistic versus gesturally organized manual input in the first place.

Thus, all evidence points to the existence of *something* that is interfacing with general perception and motor production constraints that is uniquely sensitive to aspects of specifically-linguistic input. Therefore (and again), I hypothesize that infants are born with a (i) "structure-recognition mechanism" that is uniquely sensitive to the stimulus characteristics of the input that correspond to aspects of prosodic and phonological (phonetic, syllabic) structure in natural language, which works in combination with (ii) mechanisms of general perception, and (iii) motor production constraints, in the ways specified above.

## 4.4. PREDICTIONS

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.

## 5. Language Phylogeny

Above I have provided the behavioral facts of early language ontogeny that have emerged from studies in my laboratory. It has been my primary goal to explain these behavioral facts of language ontogeny. To this end, I have advanced a theory of early language ontogeny that I will be refining and testing for many years to come. Like others, I can provide hypotheses about the relationship between the present data and language phylogeny. However, whether hypotheses about language phylogeny are viable, the behavioral observations of early language ontogeny identified above remain. In other words, 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. In many instances, this has not been the case, especially regarding hypotheses about language phylogeny that ignore the facts of signed language acquisition. Below I provide very preliminary speculations about language phylogeny that are consistent with the findings from early signed and spoken language acquisition.

### 5.1. WHY ISN'T THERE A PREFERENCE FOR SPEECH IN LANGUAGE ONTOGENY? WHAT ABOUT LANGUAGE HAS BEEN SELECTED FOR?

It has been argued that the mechanisms for producing speech were selected for first, and then came language (i.e., "syntax", e.g., Lieberman, 1984, 1991). Here I offer two alternative preliminary hypotheses, based on the premise that first "Language" was selected for - i.e., aspects of both its form and its conceptual underpinnings - and then came the means for producing it.

*5.1.1. Hypothesis A.* Particular patterns relevant to natural language structure have been selected for, but, the expressive apparatus is still in the process of being selected for. The most critical aspects of language have been selected for - its densely packed, hierarchically organized, rhythmically patterned structure, but, the modality has not yet been fully selected for. Either selection for speech has been imperfect, or selection for speech is not quite "there" yet[4]. What could this mean in terms of language phylogeny? It could mean that some form of symbolic capacity existed prior to the ability to express it. That is, perhaps we have a clue regarding a "direction of effect": Internal factors, for example, deriving from an awareness of self/consciousness, the symbol, as in X "stands for" Y, and so forth, could have exerted pressure on the means for producing its contents.

Why do most people speak? Most of us speak, but all of us have the capacity to sign in ontogeny. This fact is not trivial. Indeed, speech does have certain signaling advantages (perhaps, its speed/rate of transmission and reception). Whatever the elusive advantage is, it provided speech with an edge. However, there is no evidence for a preference for speech in language ontogeny. Again, this may imply that speech has been largely selected for, which is why most of us speak, but that the selection process has been a good, but imperfect one; we would expect this, given that nature is a "tinkerer". Perhaps, without being "goal-oriented", speech is still in the process of being selected for. Selection has occurred for "Language" - that is, aspects of its abstract structure - but it has not yet fully selected for the expressive modality, although it has come very close

4 - I thank Kevin Dunbar for first suggesting this possibility to me.

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## 6. Conclusions

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regarding existing speech perception and production mechanisms. Perhaps, in the distant future, we will see a strong preference for speech in ontogeny - but, perhaps not (again, "the tinkerer" has no "goals", as such).

*5.1.2. Hypothesis B.* It may be that the evolution of language has not occurred exclusively in terms of the mechanisms for the motor production of speech, per se. To solve the problem of differentiating between speech-linguistic versus speech-nonlinguistic information being received and expressed in the same auditory modality, perhaps "the brain" was pushed to some other level of language abstraction[5]. 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 spin off of the existence of this structure-recognition mechanism would be that humans could generate alternate 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 both demonstrate the requisite structures of natural language.

Note that this hypothesis is distinct from an hypothesis that it superficially resembles. Here it is argued that Language arose in the context of speech. The brain is consequently neurologically "wired" for speech. So, 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 mental/signaling system geared for speech. Thus, it is not surprising that speech and signed languages share common linguistic structures. First, this account does not explain *how* such common structures are possible, 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. The problem is that 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 the bilingual/bimodal children would show a preference for speech, which is not observed.

In summary, it may be that certain pressures - for example, the need to separate speech-linguistic versus speech-nonlinguistic - 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. I am well aware of the problem of applying language acquisition data to phylogenetic arguments. However, if pressed, I would say that my data render more plausible this latter hypothesis ("B").

## 6. Conclusions

In this chapter, I argue for the existence of a structure-recognition mechanism in newborns that is uniquely sensitive to particular aspects of natural language input

5 - 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.

(i.e., prosodic and sub-lexical/syllabic). I further outline how this mechanism crucially works in conjunction with motor production and general perceptual constraints in early language ontogeny. I advance the hypothesis that speech input, per se, is not critical to the content and course of early language ontogeny. Instead, linguistically-relevant structures encoded within the input are key. I further propose that 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. Indeed, the existence of naturally-evolved signed languages is used here to test, and to adjudicate between, hypotheses about early language ontogeny. Further, I suggest 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 language phylogeny. Many questions remain. I am presently conducting studies to understand better the exact nature of what I have termed the "structure-recognition mechanism", should it exist. My goal is to identify the precise dimensions of rhythm, timing, and stress variation that all newborns may be sensitive to, regardless of the modality of the language input.

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