The emergence of language: Origins, properties, processes

Siobhan Holowka de Belle

Department of Psychology
McGill University, Montreal

August, 2002

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements of the degree of Doctor of Philosophy

Your file Votre référence
ISBN: 0-612-88447-3
Our file Notre référence
ISBN: 0-612-88447-3

Abstract

The emergence of language is a phenomenon that lies at the core of higher human cognition and which continues to be the source of controversy and debate. In a series of three studies, the present thesis examined issues pertaining to language acquisition, (i) providing insight into the origins of language by addressing the question of whether the basis of babbling is fundamentally motoric or linguistic, (ii) positing new properties of babbling in order to discriminate between the linguistic and non-linguistic behaviors produced by babies, and (iii) describing the processes underlying babies' transition from babbles to first words. In Manuscript 1, using Optotrak, the manual activity of six hearing babies was examined (at ages 6, 10 and 12 months; 3 babies were exposed to a signed language and 3 to a spoken language). Analyses revealed that only the sign-exposed babies produced linguistic activity (manual babbling) at a frequency of approximately 1 Hz, and subsequent videotape analyses revealed that babbling was produced in the linguistic signing space. Non-linguistic activity was produced by both groups of babies at approximately 2.5 Hz and fell outside the signing space. In Manuscript 2, the oral activity of ten hearing babies acquiring a spoken language was examined for evidence of mouth asymmetry (between ages 5 and 12 months). Right mouth opening was observed only while the babies were babbling (reflecting left hemisphere language specialization), as contrasted with equal or left mouth opening for non-linguistic oral activity. In Manuscript

3, a combination of sources (videotapes, parental reports, interviews, and experimenter notes) was used to examine how six hearing bilingual babies acquired the meanings of words/signs across their two languages (from ages 7 to 26 months; 3 babies were exposed to a signed and a spoken language and 3 to two spoken languages). The babies constrained, organized, and used their first words/signs in similar ways, and in ways similar to monolinguals. Collectively, these three studies provide evidence for a linguistic continuum that originates with babbling, develops independent of other non-linguistic behavior, and proceeds through the emergence of first words despite cross-linguistic and cross-modal differences.

Résumé

L'émergence du langage est un phénomène fondamental de la cognition humaine qui continue à provoquer de la controverse et de la discussion parmi les chercheurs dans le domaine. Dans une série de trois études, cette thèse examine certaines questions concernant l'acquisition du langage, (i) en fournissant plus d'information au sujet des origines du langage en examinant la question du babillage (à savoir si le babillage est fondamentalement moteur ou linguistique), (ii) en identifiant de nouvelles qualités au babillage afin de permettre une distinction entre les comportements linguistiques et non-linguistiques produits par les bébés et (iii) en décrivant les procédés sous-jacents par lesquels les bébés font la transition entre le babillage et les premiers mots. Dans le manuscrit 1, l'activité manuelle de six bébés entendants a été examinée à l'aide de l'Optotrak (aux âges suivantes: 6 mois, 10 mois et 12 mois; 3 bébés ont été exposés à la langue des signes et 3 bébés à une langue parlée). Les analyses ont révélé que seuls les bébés exposés à la langue des signes ont produit de l'activité linguistique (babillage manuel) à une fréquence approximative de 1 Hz. Des analyses de bande vidéo ultérieures ont indiqué que le babillage a également été produit dans l'espace linguistique des signes. L'activité non-linguistique a été produite par les deux groupes de bébés à approximativement 2.5 Hz et a été produite à l'extérieur de l'espace linguistique des signes. Dans le manuscrit 2, l'activité orale de dix bébés entendants acquérant une

langue parlée a été examinée pour des manifestations de l'asymétrie de la bouche (entre les âges de 5 mois et 12 mois). Une ouverture du côté droit de la bouche a été observée seulement lorsque les bébés étaient en train de babiller (ce qui démontre une spécialisation de l'hémisphère gauche pour le langage) comparé à une ouverture des deux côtés de la bouche ou du côté gauche pour l'activité orale non-linguistique. Dans le manuscrit 3, une combinaison de sources (bandes vidéo, témoignages des parents, entrevues et notes prises par les expérimentateurs) a été utilisée pour examiner comment six bébés bilingues entendants ont acquis la signification de mots/signes à travers leurs deux langues (de 7 mois à 26 mois; 3 bébés ont été exposés à la langue des signes et à une langue parlée et 3 bébés ont été exposés à deux langues parlées). Les bébés ont tous contraint, organisé et utilisé leurs premiers mots/signes de manière similaire et de façon semblable aux monolingues. En somme, ces trois études suggèrent l'existence d'un continuum linguistique, qui commence par le babillage, se développe ensuite indépendamment des autres comportements non-linguistiques et continue par l'apparition des premiers mots en dépit des différences linguistiques et des modes de transmission.

Acknowledgements

My advisor, Laura Ann Petitto, taught me the importance of approaching research questions from multiple perspectives, and inspired me to acquire the methodological and theoretical means to find answers. In my pursuit of explanation and discovery I often encountered what I believed were insurmountable obstacles, and I am sincerely grateful to her for motivating me to persevere nonetheless. Through her encouraging words I learned to work independently, and through her faith in me she gave me the opportunity to succeed. As I move on, I am thankful to her for imparting her drive, dedication, and enthusiasm that served both as a source of strength and as an example.

I am indebted to my committee members David Ostry and Daniel Levitin for their kindness, advice, and feedback. I am especially grateful to them for encouraging me to trust my judgement, for supporting my decisions, and for enriching my graduate experience on the whole.

The many students, research assistants, and volunteers with whom I have worked over the past four years, gave me an opportunity to exercise my role as teacher and advisor. I thank them for their assistance and for their patience with me, as they contributed to my development as both a researcher and as a person.

The families of the babies that I studied were generous, patient, and kind beyond my expectations. I am grateful to one family in particular who gave me an opportunity to

study an extraordinary baby, Xavier. Many of the insights presented throughout this thesis were gained through my hours and hours of observing him. For all that these families have given me, I hope that I have provided answers to some of their questions by pursuing this line of research.

I thank my own family whose love, support, and encouragement have given me the strength to realize my goals. More than their praise in the good times, I have always valued their ability to listen and to support me in the more difficult times. I thank you all for being there for me when I needed you most.

Finally, I thank Darren Holowka for enriching my life as a husband, friend, and colleague. From the genesis to the culmination of this work, I thank you for teaching me, for listening to me, and for believing in me. We began this journey together and so shall we embark on the next. And as we go forth, I shall again carry your words with me: *"On this, the beginning of the next stage of your journey to knowledge and truth: Never stop asking 'Why?'"*

Table of Contents

Preface

Manuscript-Based Theses

The following is an excerpt from the McGill University Faculty of Graduate Studies and Research *"Guidelines Concerning Thesis Preparation":*

> As an alternative to the traditional thesis format, the dissertation can consist of a collection of papers of which the student is an author or co-author. These papers must have a cohesive, unitary character making them a report of a single program of research. The structure for the manuscript-based thesis must conform to the following:
>
> Candidates have the option of including, as part of the thesis, the text of one or more papers submitted, or to be submitted, for publication, or the clearly-duplicated text (not the reprints) of one or more published papers. These texts must conform to the "Guidelines for Thesis Preparation" with respect to font size, line spacing and margin sizes and must be bound together as an integral part of the thesis.
>
> The thesis must be more than a collection of manuscripts. All components must be integrated into a cohesive unit with a logical progression from one chapter to the next. In order to ensure that the thesis has continuity, **connecting texts that**

provide logical bridges preceeding and following each manuscript are mandatory.

In general, when **co-authored papers** are included in a thesis the candidate must have made a substantial contribution to all papers included in the thesis. In addition, **the candidate is required to make an explicit statement in the thesis as to who contributed to such work and to what extent.** This statement should appear in a single section entitled **"Contributions of Authors"** as a preface to the thesis. The supervisor must attest to the accuracy of this statement at the doctoral oral defense. Since the task of the examiners is made more difficult in these cases, it is in the candidate's interest to clearly specify the responsibilities of all the authors of the co-authored papers.

In accordance with these guidelines, the manuscripts included in the present thesis have only been altered from their published (in press, submitted) forms in style, not content, in order to present a unitary, cohesive work. Moreover, connecting text between manuscripts is included at the beginning of Chapters 3 and 4. Furthermore, an explicit statement of the "Contributions of Authors" on all manuscripts follows.

Contributions of Authors

Chapter Two

Petitto, L. A., Holowka, S., Sergio, L., Levy, B., & Ostry, D. (This manuscript has already been submitted & presently has the status "Revise & Resubmit"). Baby hands that move to the rhythm of language: Hearing babies acquiring sign languages babble silently on the hands. *Cognition.*

This research built on the ideas, overall theoretical goals, and methods of my advisor, Professor Laura Ann Petitto, and her collaborative Optotrak research with Professor David Ostry, former graduate student Lauren Sergio, and former research assistant Bronna Levy (who aided in earlier videotape analyses); hence, the other authors on this paper. My contribution here was substantial and significant: I collected the segments of Optotrak data and transferred them to MatLab format, analyzed the data, and coordinated the reliability checks of the data. I also analyzed the video segments, and indexed them to the Optotrak data above, coordinated the reliability checks of these data, and determined a way to present them in a form that the world could understand, evaluate, and test. I also contributed to the writing and coordination of this manuscript for submission, and I participated significantly to the publication process both by writing the first response to the reviewers when the manuscript returned from the editor of *Cognition* and by revising the manuscript accordingly.

Chapter Three

Holowka, S. & Petitto, L. A. (This manuscript has already been accepted for publication and is currently "In Press"). Left Hemisphere Cerebral Specialization for Babies While Babbling. *Science.*

In this manuscript, I discovered an original means for answering the theoretical question posed by L.A. Petitto: Is babbling a fundamentally linguistic or motoric activity? I first identified measures of cerebral laterality for language functions in adults, and then adapted and applied one such measure (mouth asymmetry) to study babies. Using this mouth asymmetry measure, I asked whether there would be differential use of a baby's mouth depending on whether the baby was babbling, smiling, or producing other non-linguistic vocalizations. I reasoned that if babbling were truly linguistic (traditionally, a left hemisphere function in adults), it should show right mouth asymmetry, as opposed to symmetrical mouth opening when producing non-linguistic vocal activity, and, further, left mouth asymmetry for smiling (thus, reflecting traditional right cerebral dominance for emotions in adults). I collected these data with the babies, analyzed the relevant segments, coordinated the reliability raters, and made the initial/original discoveries that indeed bore out these predictions. I also wrote the first draft of this manuscript for submission to *Science*, on which Petitto then commented and revised. I further wrote the first and second responses to the reviewers when the manuscript came back from *Science*, and conducted the additional analyses requested. To be sure, this manuscript represents my original and innovative research discoveries, on which I am first author.

Chapter Four

Holowka, S. Brosseau-Lapré, F. & Petitto, L. A. (2002). Semantic and Conceptual Knowledge Underlying Bilingual Babies' First Signs and Words. *Language Learning*, *52:2*.

This study was inspired by a previous study by L.A. Petitto with similar methods and findings. Francoise Brosseau-Lapré was a McGill undergraduate Honours student who assisted Petitto and me in one part of one of the four analyses within, hence, her inclusion as an author. My contribution to this study was substantial and significant: I participated in the data collection and transcription, analyzed new and previously analyzed sections of the data, offered one innovative analysis (of the four provided), and made an original observation in these data that Petitto had not observed before. I further contributed significantly to the publication process by writing the first and second responses to the reviewers and by revising the manuscript accordingly.

Chapter 1: Introduction

The emergence of language: Origins, properties, processes

"Now the whole earth had one language and one speech... And they said, 'Come, let us build ourselves a city, and a tower whose top is in the heavens; let us make a name for ourselves, lest we be scattered abroad over the face of the whole earth...' And the LORD said, 'Indeed the people are one and they all have one language, and this is what they begin to do; now nothing that they propose to do will be withheld from them. Come, let Us go down and there confuse their language, that they may not understand one another's speech...' Therefore its name is called Babel, because there the LORD confused the language of all the earth...

Genesis 11 (*New King James Version*)

The etymology of the word *babble* is evident from this Bible passage. The Tower of Babel stands as a symbolic reminder of the former linguistic unity shared by all of mankind. In differentiating this language, confusion was generated as the people were unable to understand one another's speech. Similarly, the familiar "ba-ba-ba" and "ma-ma-ma" sounds babbled by babies are met with confusion by parents, as it is unclear what (if anything) their babies are trying to communicate. Nevertheless, babies' babbles are clearly meaningful to researchers, as this behavior reveals clues into the origins of language. As language itself is a higher cognitive capacity uniquely attributed to humans, understanding its origins is a step toward better understanding the nature of our species. In order to ascertain *when* expressive language begins, we must therefore first understand the basis of babbling, the key properties that define this behavior, and the processes underlying how babies make the transition from babbles to first words. And while Jewish oral tradition suggests that passing the Tower of Babel makes you forget all you know, it is precisely the multilinguistic society originating there that now contributes to our knowledge of how language emerges in all humans.

Origins

All normally developing babies proceed through a series of stages of language acquisition. Babies' very first sounds are largely determined by the anatomical characteristics of their developing vocal apparatus. At birth, for example, reflexive crying is the only type of sound that babies emit. Oller (1980) has characterized the next few stages of babies' vocalizations as the "phonation, gooing and expansion" stages of language acquisition respectively. In the first stage, babies' reflexive sounds vary, and phonated grunts and "comfort sounds" appear. Next, by 2 to 3 months, babies goo and coo demonstrating their first resonances (pre-vowel) and constrictions (pre-consonants). Constrictions and resonances may alternate at this age, but they do not yet occur as a syllabic unit. Between 4 and 6 months babies' first consonant-like sounds emerge as they expand their phonated repertoire by experimenting with the airflow and exploring with their tongues. Partial constriction of the airflow, for example, results in the production of raspberries--the precursor to a class of sounds called fricatives--whereas complete constriction of the airflow later becomes a class of sounds called stops. Moreover, babies scream, growl, squeal, yell, and whisper demonstrating their experimentation with pitch and extremes of volume. Precursors to consonant-vowel (CV) or vowel-consonant (VC) syllables also appear at this age as babies randomly alternate their early resonances and constrictions.

Babies enter the babbling stages between ages 7 and 10 months. The first stage, syllabic babbling (also called the "canonical stage"; Oller, 1980), is characterized by well-formed syllables (i.e., alternations of articulated consonants and fully resonant vowels). Babies then duplicate their canonical CV syllables, giving rise to the next stage in development, reduplicated babbling (CVCV combinations; e.g., "mamama" or "bababa"). Later in development, at approximately 11-14 months, babies engage in variegated (rather than exactly duplicated) babbling, and variations in pitch and volume later lead to the speech-like quality of jargon babbling. Finally, between the ages of 9 and 14 months babies acquire their first words (Capute et al., 1986; Vihman and McCune, 1994), first two-word combinations (between ages 17 and 26 months; Bloom, 1975; Brown, 1973), first 50 words (at approximately 19 months; Nelson, 1973) and other classic linguistic milestones, until eventually their language matches the target (adult) form.

The developmental stages of early language acquisition have been demonstrated over time, across diverse linguistic environments, cultures, and rearing conditions, and therefore suggest that the emergence of language is under biological control (Lenneberg, 1967). Despite the regularity and timing with which the early stages of language appear, the *precise* age of onset of babbling varies from baby to baby (e.g., some babies begin producing syllabic babbles at 5 months, and others at 10 months). Thus, as in other developmental domains, the construct of "stages" is used here to denote a period where a behavior predominates, but may not be exclusively performed (Thelen, 1991). Stated differently, each of the babbling stages represents a normal *range* of ages of onset rather than the absolute age at which one would expect the behavior to appear. Moreover, not each stage of development is necessarily discrete--babies do not cease production of reduplicated babbles, only to produce the variegated variety (in much the same way that babies occasionally resort back to crawling once they've taken their first steps). Instead, the stages follow a natural linear progression (as in the aforementioned example, what is key is that crawling always precedes walking). Throughout the literature, and within the manuscripts of the present thesis, these timing differences are overcome by matching babies by their developmental age as opposed to strict chronological age (i.e., the age at which they first enter, for example, the babbling stage).

Much like the emergence of language, other normally developing motoric behaviors appear along a fixed maturational time line (with individual variation) in the first year of life. Reduplicated movements of the hands, arms, feet, and legs, for example, characterize babies' early motoric development, and generally peak between the ages of 24 and 42 weeks (Thelen, 1979). Meier, McGarvin, Zakia, and Willerman (1997), also describe silent open-close movements of the jaw (which they have termed "jaw wags") not unlike the motor stereotypies described by Thelen. Unlike the strictly motoric development of babies' limbs, however, the open-close rhythmic activity of the jaw is also paired with phonation around 6 months of age, giving rise to babies' first babbles. This therefore, leaves open the question of the true nature or basis of babbling, and in turn, the question as to precisely "when" language begins.

One possibility is that babbling is simply an extension of the vegetative and reflexive sounds produced by babies in the first few months of life. On this view, the crying, grunting, and squealing sounds present in babies' early repertoire are coupled with the rhythmic open-close patterns of the jaw. The alternations of well-formed vowels and consonants are then simply by-products of babies' opening and closing of their jaws with random tongue placements (Davis and MacNeilage, 1995, MacNeilage, 1998, and MacNeilage and Davis, 2000, have termed this the "frame" (jaw motion) and "content" (tongue placement) theory). At this point in development, around 6 months of age, babies' reduplicated sounds are akin to the repetitive movements of developing arms and legs. Babbling therefore, may simply reflect the maturation of developing motor control, no different than learning to walk or chew. It follows from this view that babbling is fundamentally motoric in nature, and that "language" only begins later in development, around the time that babies attach meaning to their sounds eventually giving rise to first words.

Alternatively, babbling may reflect babies' first attempts at productive language, a behavior distinct from developing motor control. Babies' rhythmic opening and closing of the jaw forms adult-like syllables consisting of true consonants and vowels (unlike babies' early reflexive and vegetative sounds). On this view, babbling is a behavior fundamentally linguistic in nature distinct from other developing behaviors, and thus reflects the origins of language. These competing hypotheses reflect the motoric and linguistic hypotheses of the origins of language respectively, the main tenets of which will be reviewed in Chapters 2 and 3. What follows is a review of the key defining properties of this fascinating stage of development, and a review of the processes that underlie babies' transition from babbles to the production and use of their first words.

Properties

Lenneberg (1967) described the emergence of any maturationally controlled behavior to "direct attention to *potentialities* of behavior--the underlying matrix for behaving--instead of to a specific *act*" (p.127). To understand the basis of a behavior, however, one must study the act. Thus, researchers must examine and interpret the many acts articulated by babies to fully appreciate the nature of the behavior. In the field of language acquisition, this practice has resulted in a standardized set of criteria which is applied to babies' behavior. In the case of babbling, such criteria exist and have been widely accepted in the field as best defining the syllabic babbling of babies as distinct from all other acts produced.

Babbles may be distinguished from the reflexive and vegetative sounds produced by babies in the first year of life, because only babbles conform to the following three criteria. First, babies' sounds must contain phonetic units (e.g., de Boysson-Bardies & DeBevoise, 1999; Jusczyk, 1997; Locke, 1983). Stated differently, babies must use a reduced subset of the possible sounds found in spoken language. Second, the phonetic units produced by babies must possess syllabic organization (e.g., Jusczyk, 1997; Oller & Eilers, 1988). Thus, babies must combine their phonetic units into well-formed CV or VC combinations. Third, babies' forms must be produced without apparent meaning or reference (Elbers, 1982). If babies' forms are paired with a referent, this indicates that babies have attached meaning to their forms, and have therefore begun the process of acquiring their first words. In addition to these three well-established criteria, babies' reduplicated babbles may also be identified by their characteristic CV alternations, and later variegated and jargon babbles are also produced with the natural prosody of language (e.g., de Boysson-Bardies & DeBevoise, 1999; Elbers, 1982; Juscyzk, 1997).

Taken together, these well-established criteria reliably differentiate babies' babbles from (i) the immature reflexive and vegetative sounds produced in early life, (ii) the alternations of these early constrictions and resonances, and (iii) forms that are paired with meaning or reference (i.e., first words). What is lacking from these criteria, however, is a means of distinguishing between babbles and all other motoric activity, and thus a means of determining the basis for the behavior. It is possible, for example, that babbles are simply the random placements and movements of the tongue and jaw that MacNeilage and Davis have proposed. Alternatively, babbles could represent behavior fundamentally distinct from the stereotyped activity of opening and closing the jaw. Thus, forms produced by babies according to the criteria specified here are widely accepted as babbles, but these criteria do not specify whether these forms are inherently similar to or different from motor stereotypies. Specifying new properties of these rhythmic alternations would therefore clarify whether differences between the linguistic and motoric components of babbling exist, which in turn would provide clues into the basis of babbling, and thus, the true origins of expressive language.

Processes

Around their first birthday babies enter the first word stage. This is a momentous occasion in babies' course of development, as they finally undergo the process of attaching meaning to their formerly "meaningless" sounds. The seemingly effortless manner in which infants acquire their first words has amazed parents, but in Lenneberg's words, understanding "the underlying matrix" of this act is what has captured the attention of scientists for centuries. While researchers cannot directly observe the process of labeling concepts, they can make inferences of these processes by defining first words according to the following three criteria (e.g., Vihman & McCune, 1994; see also Petitto et al., 2001), and by examining how babies use these first words. First, like babbles, words must be produced with the phonetic units found only in natural language. Moreover, for a form to be attributed lexical status, it must also have one phonetic unit in common with the adult form of the word. Second, like babbles, the forms must possess syllabic organization, but in addition, must also exhibit syllabification and stress patterns similar to that of the target form. Finally, what differentiates babbles from first words is that babies' forms must be produced in relation to a referent across contexts. Thus, the first word stage marks babies' acquisition of the arbitrary language-specific labels that denote their underlying concepts. This latter criterion is key to understanding the processes governing early language acquisition as it reveals the nature of babies' concepts at the very onset of their production of first words.

It has also been established in the monolingual literature that the meanings underlying babies' first words are constrained and organized in highly principled ways. The forms that babies produce and the errors that they make, for example, have suggested the existence of taxonomic constraints (e.g., Clark, 1973; Huttenlocher & Smiley, 1987; Keil, 1989; Leopold, 1939-1949; Petitto, 1988, 1992; Rescorla, 1980; Volterra & Taeschner, 1978). Conceptual organization of babies' first words has also been illustrated in monolingual babies (e.g., Nelson, 1973), and similar patterns in the content of these first words have been suggested (e.g., Dromi, 1987; MacWhinney, 1998; Mervis, 1984;

Nelson, 1973; Ninio & Snow, 1988; Slobin, 1985). Whether the constraints, organization and content of the semantic and conceptual underpinnings of these first words hold across babies acquiring two languages in two distinct modalities, however, remains unclear. Just as the question remains whether there exist differentiated linguistic and motoric components of babbling, it is equally unclear whether babies make differential use of the input in acquiring the meanings of their first words. Further, it is unclear whether, despite differences in the form of input across individual babies, universals exist in the semantic and conceptual underpinnings of their first words. By examining babies from new perspectives, these questions will be addressed in Chapter 4 and will provide new insight into the processes underlying all acquisition.

In sum, the origins of language have eluded researchers thus far because the basis of babbling remains controversial. Despite individual differences, all babies proceed through a prescribed series of stages of developing behavior, but in the case of babbling, it is unclear whether these acts are fundamentally linguistic or motoric in nature. A well-established set of criteria for identifying babbles exists, yet it lacks the precise properties necessary to determine the true origins of this behavior. Finally, while clues into the nature of monolingual babies' first words have been provided, it remains unknown whether these same processes underlie all of language acquisition.

To shed new light on the origins, properties, and processes of language, it was necessary to approach these research questions from new perspectives. Given the similarities between signed and spoken languages, researchers in the past have used the key differences between the modality of transmission of signed and spoken languages to test the biological assumptions of language first put forth by Lenneberg, and answer questions previously unattainable through the study of spoken languages alone. What follows is a brief review of how exploring the similarities and exploiting the differences between signed and spoken languages permits new insight to be gained into how language emerges in all babies. Then, in coupling the sign-exposed babies with the development, enhancement, and application of new techniques and methods, the specific perspectives gained from each of the manuscripts contained within the present thesis will be described.

New Perspectives

It is now well established that, like spoken languages, signed languages (i) exist for different communities in different parts of the world (i.e., just as English is the national language of the United States, American Sign Language (ASL) is predominately spoken by the American Deaf community), (ii) evolve naturally, change over time, and are not invented, and (iii) possess the same levels of grammatical organization as spoken languages including identical phonemic, phonetic, syllabic, morphological, syntactic, and pragmatic levels (e.g., Baker-Shenk, 1983; Battison, 1978; Bellugi, 1980; Brentari, 1990, 1999; Coulter, 1986; Fischer & Siple, 1990; Klima & Bellugi, 1979; Lane & Grosjean, 1980; Liddell, 1978, 1990; Liddell & Johnson, 1989; Padden, 1981; Padden & Perlmutter, 1987; Perlmutter, 1991; Sandler, 1986; Senghas, 1994; Stokoe, 1960; Supalla, 1982; Wilbur & Petitto, 1981, 1983). The phonological structure of a sign consists of four components (called parameters) and are analogous to distinctive features whereby contrasts of one feature (with the three others remaining constant) constitutes a "minimal pair" and signals a change in meaning (as in "pin" and "bin" in English), including: (1) location, (2) movement, (3) hand configuration, and (4) orientation of the palm. Each of these four parameters is comprised of a restricted set of units, which are combined simultaneously, and which are organized in rule-governed ways to form a sign that has meaning. It is from this finite and restricted set of units that all the signs in a natural signed language are built. The morphemes of a signed language (smallest units of linguistic meaning) are produced primarily through changes in movement, and syntactic information (structure of phrases and sentences) is articulated primarily through systematic changes in space. In addition, aspects of complex syntactic structure (such as negation and relative clause marking) are also conveyed through systematic facial markers.

Left hemispheric cerebral specialization for language has now been demonstrated unequivocally as being independent of language modality (Corina, Vaid, & Bellugi, 1992; Damasio, A., Bellugi, Damasio, H., Poizner, & Van Gilder, 1986; Hickok, Bellugi, & Klima, 1996; the left hemisphere controls speech output in 96% of the right-handed population, and while the situation for left-handers is less clear, few individuals have true right-hemisphere competence; Graves, Goodglass and Landis, 1982). Further, Petitto and colleagues (2000), used Positron Emission Topography (PET) to demonstrate that when signing individuals process linguistic tasks, they use brain tissue within the left hemisphere homologous to the tissue recruited by speaking individuals during similar tasks, even tissue previously assumed to be dedicated to the unimodal processing of sound and speech.

Several researchers have now established that signed languages are also acquired in similar ways and along the same maturational time course as spoken language (Charron & Petitto, 1991; Newport, 1990, 1991; Newport & Meier, 1985; Petitto, 1987, 1988, 1992, 2001). Moreover, all of the developmental stages present in spoken languages also appear in signing babies (i.e., syllabic, variegated, and jargon babbling, first-word, two-word combinations, and 50-word stages). Petitto and Marentette (1991) for example, showed that deaf babies acquiring a signed language babble on their hands in systematic ways akin to the structure found in spoken languages (the open-close rhythmic alternations of the hand constitutes a syllable in manual babbling; Liddell and Johnson, 1989; Perlmutter, 1991). The early syllables of manual babbling later take on meaning as babies acquire their first signs, and combination of signs at the same rate and pace as babies acquiring spoken language (Petitto, 1988, 1992, 2001). Moreover, Petitto (1992) has demonstrated that babies acquiring a signed language use their first words in similar ways as babies acquiring a spoken language, as evidenced by similar patterns of constraints and organization of their early lexicons.

Given the similarities across signed and spoken languages, researchers have explored the differences between the two as a way to dissociate general cognitive and communicative abilities and linguistic acts. In studies of signing adults, for example, researchers have demonstrated that linguistic signs are largely independent of non-linguistic hand gestures (e.g., Corina et al., 1992; Hickok, Bellugi, & Klima, 1996; Poizner, Brentari, Tyrone, & Kegl, 2000). Similarly, researchers have made strides in understanding the nature of signing babies' early gestures (e.g., Bonvillian, Richards, & Dooley, 1997; Cormier, Mauk, & Repp, 1998; Meier, Mauk, Mirus, & Conlin, 1998; Petitto, 1987, 1988, 1992; Petitto et al., 2001; Petitto & Marentette, 1991). In a study of sign-exposed babies' acquisition of personal pronouns, for example, Petitto (1987) demonstrated that children possess a linguistic faculty separate from other general cognitive capacities, by illustrating a dissociation between infants' non-linguistic gestures and their very first linguistic signs. More recently, Petitto and colleagues (2001) used the modality differences between signed and spoken languages to shed new light on contemporary issues in bilingualism, including whether babies differentiate between their two languages and their two modalities (see also Holmes & Holmes, 1980; Prinz & Prinz, 1979).

In much the same vein as these earlier studies, the collection of manuscripts herein, explored the differences between signed and spoken languages as a means of better understanding how language emerges as distinct from other normally developing behaviors. In a departure from previous studies however, all of the babies studied here were hearing, and thus equal in all developmental respects, and differed only in the nature of the input received (signed or spoken). In Chapter 2, for example, the competing motoric and linguistic hypotheses were addressed in order to shed new light on the origins of language. Using a technique borrowed and adapted from the field of motor control, the manual activity of three babies acquiring a signed language was compared to the manual activity of three babies acquiring a spoken language. This first-time application of technology to babies' manual articulations was paired with standard videotape methods, and also revealed new defining properties of manual babbling.

Whether babbling represents the origins of the expressive language capacity was further examined in Chapter 3 from the oral perspective. Ten babies acquiring one of two spoken languages were examined to provide new insight into the motoric and linguistic components of oral activity. Here, a well-established technique in the adult literature was applied for the first time to study babies' oral development. The results also contributed a new defining property of oral babbling that differentiated it from other non-linguistic activity.

In Chapter 4, the processes governing the emergence of babies' first words or signs were examined. Three babies acquiring two spoken languages simultaneously were compared to 3 babies acquiring a signed and a spoken language simultaneously. Here, patterns of acquisition, including how babies constrain, organize, and use their first words/signs were analyzed. A collection of new methods and techniques for examining babies' semantic and conceptual knowledge was proposed, which taken together, enhanced existing data collection techniques in the field of bilingualism. Furthermore, interpretation of the data in light of contemporary issues in bilingualism, provided new perspectives into the processes underlying all language acquisition.

Collectively, the findings from Chapters 2, 3 and 4 made original theoretical contributions to the field of child language through coupling a cross-linguistic, cross-modal sample of babies with original methods and techniques. In Chapter 5 the origins, properties and processes of language are re-examined in light of these new perspectives. Specifically, through studying the basis of babbling from both the manual and oral perspectives, new clues into the origins of language were gained, new properties of natural language were proposed, and, through examining how meaning is acquired, universal processes underlying early language acquisition were posited. Taken together, the present thesis advanced our knowledge of how language emerges in all babies.

References

Baker-Shenk, C. (1983). A microanalysis of the non-manual components of questions in American Sign Language. In P. Siple (Ed.), *Understanding language through sign language research*, (pp. 27-57). New York: Academic Press.

Battison, R. (1978). *Lexical borrowing in American Sign Language*. Silver Spring, MD: Linstok Press.

Bellugi, U. (1980). The structure of language: Clues from the similarities between signed and spoken language. In U. Bellugi & M. Studdert-Kennedy (Eds.), *Signed and spoken language: Biological constraints on linguistic form*. Dahlem Konferenzen. Weinheim/Deerfield Beach, Fla.: Verlag Chemie. 115-140.

Bloom, L. (1975). Structure and variation in child language. *Monographs of the Society for Research in Child Development*, *38* (1-2, Serial No. 149): 136.

Bonvillian, J.D., Richards, H.C., & Dooley, T.T. (1997). Early sign language acquisition and the development of hand preference in young children. *Brain Lang*, *58*(1), 1-22.

Brentari, D. (1990). *Harmonic phonology in ASL*. Doctoral dissertation, Department of Linguistics, University of Chicago. Chicago, Il., U.S.A.

Brentari, D. (1999). *A prosodic model of sign language phonology*. Cambridge, MA: MIT Press.

Brown, R. (1973). *A first language: The early stages*. Cambridge, MA: Harvard University Press.

Capute, A. J., Palmer, F. B., Shapiro, B. K., Wachtel, R. C., Schmidt, S., & Ross, A. (1986). Clinical linguistic and auditory milestone scale: Prediction of cognition in infancy. *Developmental Medicine & Child Neurology, 28*, 762-771.

Charron, F., & Petitto, L. A. (1991). Les premiers signes acquis par des enfants sourds en Langue des Signes Québecoise (LSQ): Comparaison avec les premiers mots. *Revues Québecoise de Linguistique Théorique et Appliquée, 10* (1), 71-122.

Clark, E. V. (1973). What's in a word? On the child's acquisition of semantics in his first language. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language*. New York: Academic Press.

Corina, D.P., Poizner, H., Bellugi, U., Feinberg, T., Dowd, D., & O'Grady-Batch, L. (1992). Dissociation between linguistic and nonlinguistic gestural systems: A case for compositionality. *Brain & Language, 43*(3), 414-447.

Corina, D.P., Vaid, J., & Bellugi, U. (1992). The linguistic basis of left hemisphere specialization. *Science, 255*(5049), 1258-1260.

Cormier, K., Mauk, C., & Repp, A. (1998). Manual babbling in deaf and hearing babies: A longitudinal study. In E. Clark (Ed.), *Proceedings of the child language research forum, 29*, 55-61. Stanford, CA: CSLI Press.

Coulter, G. (1986). ASL consonants, syllables, and stress: Implications for universals of prosodic structure. Unpublished manuscript, Department of Psychology, University of Illinois, Urbana-Champaign.

Damasio, A., Bellugi, U., Damasio, H., Poizner, H., & Van Gilder, J. (1986). Sign language aphasia during left-hemisphere Amytal injection. *Nature, 322*(6077), 363-365.

Davis, B. L., & MacNeilage, P. F. (1995). The articulatory basis of babbling. *Journal of Speech and Hearing Research, 38* (6), 1199-1211.

de Boysson-Bardies, B., & DeBevoise, M. (1999). *How language comes to children: From birth to two years.* Cambridge, MA: MIT Press.

Dromi, E. (1987). Early lexical development. In M. Barrett (Ed.), *The Development of Language*. London: UCL.

Elbers, L. (1982). Operating principles in repetitive babbling: A cognitive continuity approach. *Cognition, 12* (1), 45-63.

Fischer, S. & Siple, P. (Eds.) (1990). *Theoretical Issues in Sign Language Research, Vol.1*. Chicago: The University of Chicago Press.

Graves, R., Goodglass, H., & Landis, T. (1982). Mouth asymmetry during spontaneous speech. *Neuropsychologia, 20*(4), 371-381.

Hickok, G., Bellugi, U., & Klima, E.S. (1996). The neurobiology of sign language and its implications for the neural basis of language. *Nature, 381*(6584), 699-702.

Holmes, K. M., & Holmes, D. W. (1980). Signed and spoken language development in a hearing child of hearing parents. *Sign Language Studies, 28,* 239-254.

Huttenlocher, J., & Smiley, P. (1987). Early word meanings: The case of object names. *Cognitive Psychology, 19,* 63-89.

Jusczyk, P. W. (1997). *The discovery of spoken language*. Cambridge, MA: MIT Press.

Keil, F. C. (1989). *Concepts, kinds, and cognitive development.* Cambridge, MA: MIT Press.

Klima, E. S., & Bellugi, U. (1979). *The signs of language*. Cambridge, MA: Harvard University Press.

Lane, H. & Grosjean, F. (1980). *Recent perspectives on American Sign Language*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Lenneberg, E.H. (1967). *Biological foundations of language*. New York: Wiley.

Leopold, W. F. (1939-1949). *Speech development of a bilingual child: A linguist's record* (Vols. 1-4). Evanston, IL: Northwestern University Press.

Liddell, S. (1978). Non-manual signals and relative clauses in American Sign Language. In P. Siple (Ed.), *Understanding language through sign language research,* (pp.59-90). New York: Academic Press.

Liddell, S. (1990). Structures for representing handshape and local movement at the phonemic level. In S. Fischer & P. Siple (Eds.). *Theoretical Issues in Sign Language Research, Vol.1*, (pp.37-65). Chicago: The University of Chicago Press.

Liddell, S., & Johnson, R. (1989). American Sign Language: The phonological base. *Sign Language Studies, 64*, 195-278.

Locke, J. L. (1983). *Phonological Acquisition and Change*. New York: Academic Press.

MacNeilage, P. F. (1998). The frame/content theory of evolution of speech production. *Behavioral and Brain Sciences, 21* (4), 499-546.

MacNeilage, P. F., & Davis, B. L. (2000). On the origin of internal structure of word forms. *Science, 288*, 527-531.

MacWhinney, B. (1998). Models of the emergence of language. *Annual Review of Pscychology, 49*, 199-227.

Meier, R. P., Mauk, C., Mirus, G. R., & Conlin, K. E. (1998). Motoric constraints on early sign acquisition. In E. Clark (Ed.), *Proceedings of the child language research forum, 29* (pp. 63-72). Stanford, CA: CSLI Press.

Meier, R., McGarvin, L., Zakia, R.A.E., & Willerman, R. (1997). Silent mandibular oscillations in vocal babbling. *Phonetica, 54*, 153-171.

Mervis, C. (1984). Early lexical development: The contributions of mother and child. In C. Sophian (Ed.), *Origins of Cognitive Skills* (pp.339-370). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Nelson, K. (1973). Structure and strategy in learning to talk. *Monographs of the Society for Research in Child Development, 40*(2, mono): 1-97.

Newport, E. L. (1990). Maturational constraints on language learning. *Cognitive Science, 14*, 11-28.

Newport, E. L. (1991). Contrasting conceptions of the critical period for language. In S. Carey & R. Gelman (Eds.), *Epigenesis of mind: Essays on biology and cognition.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Newport, E., & Meier, R. (1985). The acquisition of American Sign Language. In D. Slobin (Ed.), *The Crosslinguistic Study of Language Acquisition,* (Vol. 1, pp. 881-938). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Ninio, A., & Snow, C. (1988). Language acquisition through language use: The functional sources of children's early utterances. In Y. Levy, I. Schlesinger, & M. Braine (Eds.), *Categories and processes in language acquisition* (pp. 11-30). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Oller, D.K. (1980). The emergence of speech sounds in infancy. In G. Yeni-Komshian, J.A. Kavanagh, & C.A. Ferguson (Eds.), *Child phonology: Vol. 1. Production* (pp. 93-112). New York: Academic Press.

Oller, D. K., & Eilers, R. E. (1988). The role of audition in baby babbling. *Child Development, 59* (2), 441-449.

Padden, C. (1981). Some arguments for syntactic patterning in American Sign Language. *Sign Language Studies, 32*, 239-259.

Padden, C. & Perlmutter, D. (1987). American Sign Language and linguistic theory. *Natural Language and Linguistic Theory, 5*, 335-375.

Perlmutter, D. (1991). Sonority and syllable structure in American Sign Language. Unpublished paper. Department of Linguistics, University of California, San Diego.

Petitto, L. A. (1987). On the autonomy of language and gesture: Evidence from the acquisition of personal pronouns in American Sign Language. *Cognition, 27* (1), 1-52.

Petitto, L. A. (1988). "Language" in the pre-linguistic child. In F. Kessel (Ed.), *Development of language and language researchers: Essays in honor of Roger Brown* (pp. 187-221). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Petitto, L. A. (1992). Modularity and constraints in early lexical acquisition: Evidence from children's first words/signs and gestures. In M. Gunnar & M. Maratsos (Eds.), *Modularity and constraints in language and cognition: The Minnesota Symposia on Child Psychology*, Vol. 25(1) (pp. 25-58). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Petitto, L. A., Katerelos, M., Levi, B., Gauna, K. Tetrault, K., & Ferraro, V. (2001). Bilingual signed and spoken language acquisition from birth: Implications for the mechanisms underlying early bilingual language acquisition. *Journal of Child Language, 28,* 453-496.

Petitto, L. A., & Marentette, P. F. (1991). Babbling in the manual mode: Evidence for the ontogeny of language. *Science, 251,* 1483-1496.

Petitto, L. A., Zatorre, R. J., Gauna, K., Nikelski, E. J., Dostie, D., Evans, A. C. (2000). Speech-like cerebral activity in profoundly deaf people processing signed languages: Implications for the neural basis of human language. *Proceedings of the National Academy of Science, 97* (25), 13961-13966.

Poizner, H., Brentari, D., Tyrone, M.E., & Kegl, J. (2000). The structure of language as motor behavior: Clues from signers with parkinson's disease. In K. Emmorey & H. Lane (Eds.), *The signs of language revisited: An anthology to honor Ursula Bellugi and Edward Klima* (pp. 509-531). Mahwah, NJ: Lawrence Erlbaum & Associates.

Prinz, P., & Prinz, E. A. (1979). Simultaneous acquisition of ASL and spoken English: In a hearing child of a deaf mother and hearing father. *Sign Language Studies, 25,* 283-96.

Rescorla, L. (1980). Overextension in early language development. *Journal of Child Language, 7,* 321-335.

Sandler, W. (1986). The spreading hand autosegment of American Sign Language. *Sign Language Studies, 50,* 1-58.

Senghas, A. (1994). Nicaragua's lessons for language acquisition. *Signpost, 7*(1), 32-39.

Slobin, D. (1985). Crosslinguistic evidence for the language-making capacity. In D. Slobin (Ed.), *The crosslinguistic study of language acquisition: Theoretical Issues*, Vol. 2(1) (pp. 1157-1256). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Stokoe, W. (1960). Sign language structure: An outline of the visual communication systems of the American Deaf. *Studies in Linguistics, Occasional Papers 8*. University of Buffalo.

Supalla, T. (1982). Structure and acquisition of verbs of motion and location in American Sign Language. Doctoral dissertation, Department of Psychology, University of California, San Diego. La Jolla, CA., U.S.A.

Thelen, E. (1979). Rhythmic stereotypies in normal human babies. *Animal Behavior, 27,* 699-715.

Thelen, E. (1991). Motor aspects of emergent speech: A dynamic approach. In N. A. Krasnegor, D. M. Rumbaugh, R. L. Schiefelbush, & M. Studdert-Kennedy (Eds.), *Biological and behavioral determinants of language development* (pp. 339-362). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Vihman, M., & McCune, L. (1994). When is a word a word? *Journal of Child Language, 21*(3), 517-542.

Volterra, V., & Taeschner, T. (1978). The acquisition and development of language by bilingual children. *Journal of Child Language, 5,* 311-326.

Wilbur, R. & Petitto, L.A. (1981). How to know a conversation when you see one. *Journal of the National Student Speech Language Hearing Association, 9*, 66-81.

Wilbur, R. & Petitto, L.A. (1983). Discourse structure in American Sign Language conversations. *Discourse Processes, 6:3*, 225-241.

Chapter 2: Manual Forms

Manuscript 1

Baby hands that move to the rhythm of language:

Hearing babies acquiring sign languages babble silently on the hands

Laura Ann Petitto

Siobhan Holowka

Lauren E. Sergio

Bronna Levy

David Ostry

Petitto, L.A., Holowka, S., Sergio, L.E., Levy, B., & Ostry, D.J. (Under Review). Baby hands that move to the rhythm of language: Hearing babies acquiring sign languages babble silently on the hands. *Cognition*.

Under review for publication in *Cognition*.

Abstract

The "ba, ba, ba" sounds universal to babies' babbling around 7 months captures scientific attention because it provides insights into the mechanisms underlying language acquisition and vestiges of its evolutionary origins. Yet the prevailing mystery is what is the biological basis of babbling, with one hypothesis being that it is a non-linguistic motoric activity driven solely by the baby's emerging control over the mouth and jaw, and another being that it is a linguistic activity reflecting the babies' early sensitivity to specific phonetic-syllabic patterns. Two groups of *hearing* babies were studied over time (ages 6, 10, 12 months), equal in all developmental respects except for the modality of language input (mouth vs hand): Three hearing babies acquiring spoken language and an extraordinary group of 3 hearing babies acquiring sign language (not speech); despite this latter group's exposure to sign, the motoric hypothesis would predict no group differences in hand activity because their language acquisition does not involve the mouth. Using innovative quantitative Optotrak 3-D motion-tracking technology, we discovered that the specific rhythmic frequencies of the hands of the sign-exposed hearing babies differed depending on whether they were producing linguistic activity, which they produced at a low frequency of approx 1 Hz, versus non-linguistic activity, which they produced at a higher frequency of approx 2.5 Hz—the identical class of hand activity that the speech-exposed hearing babies produced nearly exclusively. Surprisingly, without benefit of the

mouth, hearing sign-exposed babies alone babbled systematically on their hands. We conclude that babbling is fundamentally a linguistic activity and explain why the differentiation between linguistic and non-linguistic hand activity in a single manual modality (one distinct from the human mouth) could only have resulted if *all* babies are born with a sensitivity to specific rhythmic patterns at the heart of human language and the capacity to use them.

Acknowledgements

We thank the deaf and hearing families that participated in this study. We thank Kevin Dunbar and Darren W. Holowka for comments on earlier versions of this manuscript. We also thank Ulana Harasmowycz, Kristine Gauna, and Ioulia Kovelman for assistance with aspects of the data transcription and details of manuscript preparation. We thank research assistant, Trygve Armour, for his help on the statistical analyses involved in the final videotape replication of our original Optotrak findings. Crucially, we are extremely grateful to Professor James Ramsay of McGill's Psychology Department for his expert guidance and help on all aspects of the statistical methods and analyses used in this study. A much shorter version of only one part of the present study (Optotrak findings) appeared in *Nature*. See Petitto, L. A., Holowka, S., Sergio, L. E. & Ostry D. (2001). Language rhythms in baby hand movements. *Nature, 413*(6), page 35-36. This research was funded by the following grants to L. A. Petitto: Social Sciences and Humanities Research Council of Canada, Natural Sciences and Engineering Research Council of Canada, The Spencer Foundation (U.S.A.), and a research operating start-up grant from Dartmouth College. Petitto also thanks The Guggenheim Foundation for a generous fellowship.

Baby hands that move to the rhythm of language: Hearing babies acquiring sign languages babble silently on the hands

Introduction

Baby babbling fascinates us because of its regular onset and structure in all healthy humans beginning at around 7 months. Of late, babbling has been at the nexus of a lively scientific controversy because it is understood to provide a key window into the origins of language in young humans as well as reflecting vestiges of the evolutionary origins of language in our species.

Unlike the crying and vegetative sounds also produced by babies in early life, "babbling" (more technically referred to as "syllabic" or "canonical" babbling) only involves vocalizations that exhibit these key properties: (i) use of a reduced subset of possible sounds (phonetic units) found in spoken language (e.g., de Boysson-Bardies & DeBevoise, 1999; Jusczyk, 1997; Locke, 1983), (ii) possession of syllabic organization (well-formed consonant-vowel, CV, clusters; e.g., Jusczyk, 1997; Oller & Eilers, 1988), and (iii) use without apparent meaning or reference (Elbers, 1982); typically, baby's babbling forms are also reduplicated, produced with the general prosodic (rhythmic, timing, stress) contours of natural language and follow characteristic stages (e.g., de Boysson-Bardies & DeBevoise, 1999; Juscyzk, 1997; Elbers, 1982). Some have noted that an individual baby's preferred early babbling forms, for example, "bababa," can be continuous with the predominant phonetic forms that appear among its first words, like "baby" (e.g., Vihman, 1985; for an excellent account of babbling see de Boysson-Bardies & DeBevoise, 1999).

Although babbling is judged to be one of the monumental milestones in early development, the major controversy in contemporary science concerns what is its basis. One possibility is that babbling is a fundamentally motoric behavior, deeply akin to the brain's maturation of other general motor capacities that are also emerging during this time such as sitting, standing and walking (Van der Stelt & Koopmans-van Bienum, 1986)—indeed, exhibiting the same pattern of false starts, starts and stops along the way to motor mastery. On this view, babbling is a kind of motor flexing of the mouth and jaw muscles as the brain grows better at mastering the fundamentally motoric job of forming speech sounds. Ultimately, newly mastered speech productions are wed through classical association and learning principles with the ambient linguistic system, hence the appearance of baby's first word at around 12 months (e.g., Studdert-Kennedy, 1991). Interestingly, some researchers have viewed the assertion that baby babbling in ontogeny is first a non-linguistic motoric activity that later takes on linguistic status as supporting one phylogenetic claim about the evolutionary origins of language in which speech production mechanisms evolved first, then language. In other words, the view that human language as we know it today ostensibly evolved its present grammatical structure because of selection pressures arising from constraints on the mechanics of speech production, *per se* (Liberman, 2000; but see especially Pinker & Bloom, 1990, and Rizzolatti & Arbib, 1998).

The alternative is that babbling is a fundamentally linguistic activity and part of a developing complex system of mechanisms that contribute to an individual's mature knowledge of language. Here, the presence of fundamentally linguistic units in babbling, such as repeated consonants and vowels, in combination with its universal onset and highly regular structure, have lead to the conclusion that babbling is a robust index that aspects of human language acquisition are under biological control.

In the present paper, we test the motoric versus linguistic hypotheses about the basis of babbling in babies. But before explaining how, we first take a closer look at these two hypotheses because one thing should now be clear: Over the years the investigation of babbling in babies has expanded into a topic of great importance with very high theoretical stakes. Scientists now understand that knowledge of the basis of babbling will provide insight into its biological foundations and, by extension, the biological foundations of human language. It will reveal the nascent mechanisms subserving language in the species, including at what point in development these mechanisms emerge, and what types of input are necessary for their development.

Motoric hypothesis. Some researchers suggest that the syllabic structure of babbling is determined by the development of the vocal tract, and the neuroanatomical and neurophysiological mechanisms subserving the motor control of speech production (e.g., Davis & MacNeilage, 1995; Locke, 1983; MacNeilage & Davis, 2000; Studdert-Kennedy, 1991; Thelen, 1991; Van der Stelt & Koopmans-van Bienum, 1986). Davis and MacNeilage (1995) state that the consonant-vowel alternations characteristic of syllabic babbling are determined by rhythmic mandibular oscillations. According to the frame/content theory, MacNeilage (1998) proposed that syllabic "frames" may have derived from the cyclic alternations of the mandible present from the onset of babbling. These frames may have evolved when mastication took on communicative significance in apes. The "content" of syllables, on the other hand, which is provided by a finite number of fixed consonant-vowel sequences, is a direct consequence of lip and tongue placement. MacNeilage and Davis (2000) have recently supported the frame/content theory with empirical evidence. In a statistical analysis of 10 babies raised in an English environment, three patterns of syllabic babbling were observed. This finding, coupled with similar findings in babies raised in 5 other language environments, led MacNeilage and Davis to propose a universal pattern of babbling which is guided by the physiological properties of the jaw (i.e., the syllabic "frames").

According to the frame/content theory, modulations of jaw oscillations then account for the next phases in human linguistic development, as the child proceeds from the prespeech to the first-word stage. The rhythmic alternations of the jaw first appear at approximately 5 months of age in the human child and are accompanied by phonation at approximately 7 months of age (Meier, 1997; see also Locke, Bekken, McMinn-Larson,

& Wein, 1995). Through general association and learning strategies babies' babbles are subsequently paired with meaning, and only then, after maturation of motor control has been completed, does a discreet linguistic system emerge giving rise to babies' production of words. While the frame/content theory supports the idea that babbling is under maturational control and develops in a similar manner to other aspects of motoric development, it does not take into account principles of linguistic development; early babbling and more specifically, early language development, simply emerges as a biological "side-effect" or "natural accident" of motor development.

In response to MacNeilage, Davis, and other proponents of the motor driven theory of babbling, several researchers have examined the early vocal productions of babies cross-linguistically to determine whether a universal pattern of babbling "content" exists (e.g., de Boysson-Bardies, 1993; de Boysson-Bardies & DeBevoise, 1999; Elbers, 1982; Oller & Steffens, 1994; Vihman, 1992). Vihman (1992), for example, observed a common pattern of consonant-vowel alternation bound by the motoric constraints of the jaw, which is consistent with the frame/content theory. However, the more salient finding from this study was large individual differences in the consonant-vowel associations found in the most common syllables of babies exposed to the same language. Given the common physical characteristics of the jaw of babies at the babbling stage, it is difficult to explain these production differences in terms of a strictly motoric theory of babbling. As noted by de Boysson-Bardies, "...babies have a particular type of vocal apparatus at their disposal, but the constraints this apparatus puts on the production must be distinguished from the use to which babies put it" (1993, p. 361).

Linguistic hypothesis. Proponents of the linguistic hypothesis of babbling view it as one key mechanism that permits babies to discover and to produce the patterned structure of natural language (e.g., de Boysson-Bardies, 1993; de Boysson-Bardies & DeBevoise, 1999; Jusczyk, 1993, 1997; Petitto, 1993; Vihman, 1996). Babies are sensitive to the patterns in natural language that correspond to the temporal and rhythmic characteristics of phonology (Jusczyk, 1986; Mehler, Lambertz, Jusczyk, & Amiel-Tison, 1986). Thus, patterned input with syllabic and phonetic organization may be what triggers babies' babbling (Petitto & Marentette, 1991). The production of babbles, in turn, allows babies to discover the particular restricted set of phonetic units and permissible combinations of their target language. This view is consistent with Vihman's (1996) observation that some babies initially possess a large range of possible sound sequences, which only emerge as a canonical pattern after having matched their initial sound repertoire with the adult form of the language.

According to this linguistic hypothesis of babbling, the open-close alternations of the jaw characteristic of babbling reflect the maximally contrasting syllabic units of the target language. This hypothesis lies in sharp contrast to the motor driven account which states that babbling is simply a byproduct of motoric development. Through babbling, babies can then actively discover the phonological inventory of their native language upon which all the words of their language will be built. This suggests that babies may have peaked sensitivity to the rhythmic patterning of language about the size of the babbling syllable that babies produce (Mehler et al., 1986; Petitto, 1993; Petitto, 2000; Petitto, Holowka, Sergio & Ostry, 2001), which may afford them with the means to segment the linguistic stream and to discover word boundaries and enables the acquisition of meaning and first words. Thus, by attending to the structured rhythmic and temporal patterns of the ambient language and, crucially, by producing them, the baby acquires the rudiments of its language (Petitto et al, 2001). In this respect, babbling is viewed as a systematic and fundamentally linguistic behavior, which reflects the particular patterns inherent in natural language, and which develops in addition to general motoric development (see also Elbers', 1982, cognitive continuity theory, and Vihman's, 1996, model which considers both motoric and linguistic influences). While providing a potential account of babies' babbling, the linguistic hypothesis of babbling also raises the following question: How much of language development is under biological control, and how much of it is due to influences of the ambient language?

In addressing this question, some researchers argue that audition is necessary to ensure normal language development (Locke, 1990; Locke & Pearson, 1990; Oller & Eilers, 1988; Oller, Eilers, Bull, & Carney, 1985). In the course of examining deaf or hearing-impaired babies devoid of any known cognitive deficits, Oller and Eilers (1988) observed these babies to have reduced and/or delayed vocal canonical babbling as compared to hearing babies. Locke (1990) further elaborated on this point by stating that auditory stimulation from both the environment and the auditory feedback that babies receive from their own vocalizations is crucial for vocal babbling to emerge. Locke and Pearson (1990) further qualified this observation by examining a tracheostomized, aphonic girl with normal hearing. Following decannulation she demonstrated delayed vocal development. Collectively, these findings led researchers to conclude that the role of audition is crucial to early language development in general, and babbling in particular.

Petitto and Marentette's (1991) discovery of "manual babbling" on the hands of profoundly deaf babies challenged the above views in at least two fundamental ways. First, the discovery challenged the notion that the opening-closing of the mouth and jaw, and a baby's emerging neurological control over them, is the exclusive driving force underlying the behavior in development—because these babies were deaf and were not using their mouths/jaws, only their hands. Second, it challenged the assertion that audition *alone* is critical for babbling to emerge, and suggested instead that babies require patterned linguistic (as opposed to strictly auditory) cues from the environmental input in order for babbling (hence, human language acquisition) to proceed.

Why "babbling" on the hands? In the course of examining profoundly deaf babies exposed to a sign language, Petitto and Marentette (1991) observed a class of hand activity that was like no other. It was not like the deaf babies' gestures and not like anything else that they did with their hands; nor was it like any class of hand activity observed in the hearing control babies. As in the criteria standardly used to establish the existence of vocal babbling in hearing babies, this unique class of hand activity in the deaf babies (i) contained a reduced subset of the possible linguistically relevant "sign-phonetic" units in natural sign languages, (ii) possessed "sign-syllabic" organization, and (iii) was produced in meaningless ways; this hand activity was also reduplicated, produced with the general prosodic (rhythmic, timing, stress) contours of natural sign languages, followed the identical characteristic stages observed in vocal babbling, and each individual deaf baby's preferred early babbling sign-phonetic form was continuous with the predominant sign-phonetic forms that appeared among its first signs. Petitto & Marentette had discovered "babbling" in profoundly deaf babies, albeit on the human hand.[1]

Moreover, Petitto (1993) observed through qualitative analyses that the reduplicated temporal patterning of the sign syllables produced by the deaf babies appeared to be fundamentally different from the temporal patterns of all other hand and arm movements. Yet the precise physical, quantitative measurement of the phenomenon was not understood.

Recently, researchers have corroborated Petitto and Marentette's manual babbling finding in another group of babies (Cormier, Mauk, & Repp, 1998; Meier & Willerman, 1995). While both Meier and colleagues and Petitto and Marentette have observed that deaf babies indeed produce manual babbling, Meier's team also asserts that hearing babies produce similar hand activity. Further they viewed such ostensible similarities between deaf and hearing babies' manual babbling as demonstrating that all baby babbling—be it on the hands or tongue—is therefore a fundamentally motoric activity, wholly commensurate with MacNeilage's (1998) frame/content theory. While Meier and Willerman (1995) suggested that manual babbling requires the coordination of proximal and distal articulators (e.g., shoulder and wrist, respectively), phonetic criteria for coding manual babbles were not specified. But this omission is crucial. In all studies of vocal babbling, as well as in the manual babbling studies of Petitto and Marentette, the attribution of "babbling" is applied only after using strict, standard criteria. Specifically, first a system of standard diacritics is used to characterize the physical properties of vocal/hand activity. These attributions are further subjected to standard psycholinguistic frequency and distributional analyses to identify possible phonetic units *for the child* (rather than for the adult researcher) and their combinatorial properties (the basic phonetic and syllabic units and their sequencing regularities). Having established a possible set of phonetic/syllabic forms, the criteria for "babbling" is then applied (see above, and de Boysson-Bardies & DeBevoise, 1999; Elbers, 1982; Locke, 1983; Oller & Eilers, 1988). Thus, it is possible that the coding system of Meier and his colleagues did not reliably differentiate between linguistic and non-linguistic hand activity in the deaf (acquiring sign) and the hearing (acquiring speech) babies.

Despite the methodological concerns raised here, the studies by Meier and colleagues suggest an intriguing hypothesis: Perhaps the "manual babbling" observed in deaf babies is not "babbling" at all, but instead is hand activity fundamentally similar to that observed in all babies, even hearing babies not exposed to sign languages. All babies produce an array of hand activity in early life as a consequence of developing motor control. Thelen (1979, 1981, 1991), for example, has described the emergence of repetitive, cyclic movements involving rotation around an axis or simple flexion and extension as rhythmic stereotypies. The frequency of rhythmic stereotypies (including the oral and manual articulators) peaks between 24 and 42 weeks of age, and then declines in the last fifth of the year. The regularity of onset ages of these behaviors suggests that they are on a maturational timetable for the development of neuromuscular pathways. Further, baby motoric stereotypies are not observed in parents or siblings making it unlikely that these types of activities are imitated or emerge as a result of extrinsic factors.

Also between the ages of approximately 6 and 10 months, babies enter the syllabic babbling stage. Recall that at this stage in development, babies' productions possess well-formed consonant-vowel reduplications (e.g., ba-ba-ba). Stated differently, while babbling, babies produce repetitive, cyclic open-close movements of their jaws, much like the fundamentally motoric stereotypies observed by Thelen. Hence, at this particular stage in development the motoric stage parallels the linguistic stage, but differs in one critical respect: no clues from the input are necessary for its emergence.

To summarize, the field of early child language is at a fascinating juncture. In an attempt to gain insight into the origins of language in young babies, researchers have turned to studies of vocal babbling. On the one hand, MacNeilage and colleagues maintain that vocal babbling, and by extension human language, evolves from the fundamentally non-linguistic maturation of the motor development of the oral articulators that only later take on linguistic significance as the child learns associations between their natural ability to produce sounds and word meanings in the world around them. On the other hand, de Boysson-Bardies, Jusczyk, Vihman and others say that babbling is determined by the child's sensitivity to and production of abstract, linguistic units and their distributional patterns from the very beginning. For a brief moment in time, it appeared that the competing motoric-linguistic hypotheses might be resolved with the finding by Petitto and Marentette, in which they showed that deaf babies produce complex sign-phonetic and syllabic babbling units on their hands. This new evidence suggested that deaf babies babble even though they neither hear speech nor produce speech sounds--thereby providing support for the linguistic view. In response to Petitto and Marentette's findings, Meier and his colleagues suggested that deaf babies exposed to sign language and crucially hearing babies exposed to spoken language *both* produce rhythmic manual babbling that is fundamentally similar. Given that these hearing babies acquiring speech never saw sign language input, and given Meier's claim that they, like deaf sign-exposed deaf babies, are producing rhythmic "manual babbling," this renewed the hypothesis that *all* babbling is governed exclusively by motoric principles. The key question is this: Is the rhythmic hand activity in babies exposed to sign language and the rhythmic hand activity in babies exposed to spoken language indeed fundamentally similar?

Hypothesis testing. In the present study we tested the motoric versus linguistic hypotheses by taking an entirely novel route. To pose the strongest possible test of these two hypotheses, we chose to study two groups of *hearing* babies. One group of hearing babies were being exposed to spoken language from birth (with no sign language input whatsoever). One group of hearing babies were receiving no systematic exposure to spoken language whatsoever, only sign language input from their profoundly deaf parents.

Crucially, the two hearing baby groups studied here were equal in all developmental respects, with the only difference being in the form of the language input that they received, by tongue or by hand. To be sure, all of these babies can and do hear, and all of the babies can and do produce vocalizations. This then shifts the focus from the presence of audition and use of the mouth to the presence and use of patterned linguistic cues in the input and the human baby's capacity to make use of them. This is the key prevailing hypothesis that the hearing babies acquiring sign allow us to test: Is it audition/the mouth that is key (peripheral speech production/hearing mechanisms) that drive babbling/language acquisition or the species' more central and specific sensitivity to specific patterns in the input that correspond to aspects of the patterning of natural language? We were also interested in discovering whether the hearing sign-exposed babies would produce rhythmic hand babbling and whether they would produce other rhythmic hand activity--both in the same manual modality. If so, we were especially eager to learn whether there existed a principled and patterned separation between the two. We were further interested to learn the extent to which these sign-exposed hearing babies' hand activity (be it rhythmic "manual babbling" or other rhythmic hand activity) was fundamentally similar or dissimilar to that of our hearing babies who never viewed signs. Finally, as will be seen below, we chose to study sign-exposed hearing babies with innovative Optotrak, opto-electronic position-tracking, technology. Here, diodes were placed on all babies' hands, which permitted quantitative measurements of a human baby's hands in our pursuit to adjudicate between the motoric versus linguistic underpinnings of human language.

Predictions. Two competing hypotheses have been offered to account for the presence of similar structures unique to babbling in both the manual and vocal modes. The motoric hypothesis suggests that babbling in both modes is simply a stereotyped behavior controlled by the mechanisms subserving general motor development. Because hearing babies exposed to sign language do *not* use their mouth and jaw to learn speech (which presumably makes possible the babbling behavior), the motoric hypothesis therefore predicts that their hand activity should be fundamentally similar to that of hearing babies acquiring spoken language. Said another way, this view predicts that rhythmic hand activity will be independent of patterned linguistic input and thus fundamental similarities should be seen in the hand activity across the two groups of hearing babies.

The linguistic hypothesis suggests that babbling reflects the child's emerging discovery of the underlying patterning of natural language structure, beginning with the tacit identification of its meaningless set of units (phonetic units) and their combinatorial regularities (syllables). If babies are born with sensitivity to specific rhythmic patterning that is universal to all languages, even signed ones, then this view predicts that differences in the form of language input should yield differences in the hand activities of the two groups. Specifically, fundamental differences should be observed between the *linguistic* rhythmic hand activity and the *non-linguistic* rhythmic hand activity in babies exposed to a sign language as compared with those exposed to speech. Further, this view predicts similarities should exist between both sign-exposed and speech-exposed babies' *non-linguistic* rhythmic hand activity.

Participants

Six hearing babies were studied in 60-minute experimental sessions, at approximately 6, 10, and 12 months of age in two groups. These ages were chosen to compare the babies' motoric versus linguistic development, as this age range corresponds to both developing motoric stereotypies, and to developing linguistic activity (syllabic babbling). The sign-exposed (experimental) group consisted of the extremely rare situation of 3 hearing babies of profoundly deaf parents who received no *systematic* exposure to spoken language in early life and were instead exposed exclusively to sign language input[2]. The case of babies E1 and E2 one parent signed Langue des Signes Québécoise (LSQ, used in Québec and other parts of French Canada) and the other signed American Sign Language (ASL, used in the United States and parts of Canada). The profoundly deaf parents of baby E3 signed LSQ only. The speech-exposed (control) group consisted of the more typical situation of 3 hearing babies of hearing parents; parents of babies C1 and C2 spoke English, and parents of baby C3 spoke French, and received no sign language input. Table 1 provides the precise ages of all subjects at each of the three experimental sessions.

Methods

Babies were seated in a baby car seat located in our Optotrak Laboratory at McGill University, which had brightly-colored wall partitions to shield them from viewing the equipment, and which was filled with baby posters, blankets and hanging mobiles. First, infrared emitting diodes (IREDs) were placed on the baby's hands (below) while one of the parents played with the baby. After this, Optotrak sensors tracked the trajectory and location over time of the baby's hands while the baby engaged in a variety of play activities. For example, the baby was presented with age-appropriate toys (e.g., a rattle, stuffed bunny, plush ball) that were first shown to the baby and then given to it. Other activities included one of the parents playing peek-a-boo games with the baby or talking/signing to the baby while looking in a mirror, or an activity where mom simply smiled at the baby or another where mom and experimenter conversed while the baby looked on. The goal was to create relaxed, but varied contexts in which babies would have an opportunity to produce as wide a range of hand activity as would be natural to the age.

All sessions were recorded using Optotrak (Northern Digital Inc., Waterloo, ON, Canada). Although Optotrak technology is well established in the motoric development field (e.g., Ostry, Vatikiotis-Bateson, Gribble, 1997; Sergio & Ostry, 1995), the present study is the first study to our knowledge that has applied Optotrak technology to studies of babies' early linguistic development. The sensors of the Optotrak system can accurately measure the location over time and trajectory of IREDs placed on the babies' limbs with a precision of 0.1 millimeters even at high sampling frequencies. Eight IREDs (four on each the left and the right hand/arm) were strategically placed on the babies' hands and forearms: Two adjacent IREDs were placed on the back of both the right and the left hands of the babies. An additional IRED was placed on the ventral surface of each wrist near the baby's thumb. A fourth IRED was placed on the dorsal surface of the forearm three to five centimeters proximal to the wrist. As the IREDs are tiny and lightweight, interference with the babies' movements was minimal. Thus, the three dimensional location of the limbs over time can be measured with high precision.

Crucially, Optotrak computations are calculated *blind* to videotape reference to the babies' hands, thereby providing the most accurate and rigorous quantitative analysis of moving hands to date. In particular, it provides a significant advance over previous subjective classification methods whereby researchers look at baby videotapes exclusively and decide whether they think a particular hand activity is or is not a babble (e.g., Cormier et al., 1998; Meier et al., 1998; Meier & Willerman, 1995; Petitto & Marentette, 1991). To be clear, the data yielded from Optotrak recordings are strictly numeric representations of the babies' hand/arm movements. There is no baby. There are no hands.

Independently, on-line videotapes were made of all babies for post-Optotrak analyses. The babies' hand activity in all three sessions was videotaped on two S-VHS videocassettes from two camera angles. The S-VHS video recordings of the babies were transferred onto Hi-8 videocassettes formatted with a time code that was precisely matched with the corresponding time code provided by the Optotrak recordings. Thus, at any given time, data from both the Optotrak and video recording methods were available.

Initially we recorded 2082 movement segments across all babies and ages. We defined a *movement segment* as any hand activity produced by the babies involving a single type of movement. An open-close movement of the hand, for example, would be considered one movement segment. The start of a new movement segment was indicated if a different type of movement then began (e.g., a waving motion of the hand, as in waving "goodbye"). All movement segments in which there were objects in the babies' hands, and segments of activity which involved babies making contact with an object (e.g., toy, car seat, adult), were excluded from all analyses. Likewise, any activity that was not fully within the field of view of the cameras was excluded (e.g., activity that was blocked by an adult, or by the babies' chair). For these reasons, 633 movement segments were excluded from the total corpus of data. From the remaining 1449 movement segments recorded, 595 segments were produced by the sign-exposed group and 854 segments by the speech-exposed group. As would be expected in equal 60-minute experimental sessions, the number of movement segments that the babies produced differed across babies and ages (i.e., some babies produced more activity than others, and the amount of activity varied over time--due to this fact, and for ease of comparison across babies, here, and in all subsequent analyses, the data are reported in percentages; see Table 2). Thus, to ensure that a representative sample of the babies' manual activity was analyzed, we used stratified random sampling to obtain 400 movement segments (200 per group) for Optotrak and, subsequently, for video analyses. So, for example, of the 595 movement segments produced by the sign-exposed group, 75% of this activity was produced at 6 months, 16% at 10 months and 8% at 12 months. In obtaining 200 movement segments, these same proportions (percentages) were held across all ages such that 75% of the 200 segments were produced at 6 months, 16% at 10 months, and 8% at 12 months. The identical procedure was applied to the speech-exposed babies' data, also yielding 200 movements segments (see Table 2).

We expected to see the majority of all babies' manual activity produced between 6 and 10 months (irrespective of the nature of the activity, be it linguistic or non-linguistic), because both normally developing motor stereotypies (Thelen, 1979, 1991), and manual babbles (Petitto & Marentette, 1991), peak during this period of development. What is important to note, however, is that manual activity continued to be produced through to 12 months, and that the precise amount of activity produced at any given age differed by individual baby. This is due to the fact that individual differences across babies result in varying ages of onset of developing behaviors (much in the same way that all normally developing babies begin walking by their first birthdays, but a range certainly exists for when babies actually achieve this milestone). Moreover, the continued production of any given behavior differs by baby throughout development (in learning to walk, some babies will continue crawling for a much longer period of time than others; similarly, babies will continue to babble even after the production of their first words). This observation therefore highlights the importance of collecting and analyzing data over the normal age *range* of emerging behavior (i.e., from approximately 6 to 12 months), rather than exclusively at the average age (i.e., at approximately 7 months) that researchers would expect the behavior to appear.

Optotrak recordings. At a sampling rate of 100 Hertz, the Optotrak system recorded the time-varying three-dimensional positions of the IREDs on the babies' hands/arms. Each movement segment was analyzed using commercially available data analysis software (MATLAB, The Mathworks Inc., Natick, MA, USA). The raw three-dimensional position data from each IRED was first analyzed to select those that most consistently captured the babies' movement (i.e., were seldom obscured), and yielded the final two IREDs (one from each hand, per baby) that provided the data for all subsequent analyses (i.e., the IRED nearest to the thumb on each hand).

Multiple kinematic measures were then calculated for each movement segment. First, the resultant vector of the x, y, and z position data over time was computed to give the trajectory of the hand in three-dimensional space. This trajectory was then differentiated to give the tangential velocity of the hand throughout the movement segment. From these measures, the frequency (in Hertz) was calculated for each cycle of hand activity within a movement segment. As is standard, movement start was defined as 10% of the maximum velocity of the cycle, and movement end was the point at which the tangential velocity reached 10% of the peak cycle velocity (Sergio & Ostry, 1995). The frequency for a given movement segment was determined by taking the average of the frequencies of all the complete cycles in that movement segment. This procedure yielded frequency values (in Hertz) for all 400 movement segments.

Video recordings. After Optotrak analyses were completed, then temporal matching of the Optotrak data to the videotaped data was performed for all 400 movement segments. By matching the frequency values of the movement segments provided by the Optotrak technology with the corresponding videotaped data of the babies' hand activity, we were able to see for the first time what the babies were actually doing during a particular Optotrak segment.

In addition to seeing what the babies were doing during Optotrak segments, we were able to transcribe and subsequently analyze the precise nature of the hand activity performed by the babies. We did this by transcribing and entering into a computer database all of the movement segments using a standard, widely used transcription system (below) that permitted a direct comparison of the hand activity of both groups of babies (Petitto & Marentette, 1991). This previously established transcription system enabled us to reliably differentiate between manual babbles, gestures, and the non-linguistic, motoric hand activity produced by all normally developing babies.

Following Petitto and Marentette (1991), for each of the 400 movement segments produced by the babies we transcribed the following: (i) The physical form of the babies' hands using a set of diacritics that was first created by the sign linguist, William Stokoe (1960) to be analogous to the International Phonetic Alphabet used in the transcription of spoken languages (but created here for the transcription of signed languages) and that has been perfected over several generations of sign linguistic research (e.g., see

Brentari,1999; Neidle, Kegl, MacLaughlin, Bahan, & Lee, 2000; Petitto, 1987); here, internal features of the human hand is transcribed along several dimensions (e.g., handshape, location in space, palm orientation, movement). (ii) All forms were transcribed according to the manner of use, for example, whether the form was used with or without objects in hand, whether the form was used referentially and/or with apparent communicative intent, whether the form was a standard sign in ASL or LSQ (e.g., Petitto et al., 2001; see also, Holowka, Brosseau-Lapré, & Petitto, 2002). (iii) Following standard methods used for the identification of potential vocal babbles in hearing babies (e.g., Oller & Steffens, 1994), all forms that were produced *without* reference and/or apparent communicative intent, and all forms that were not genuine attempts to sign were analyzed for the presence/absence of systematic physical organization using standard child language frequency and distributional analyses (e.g., Petitto et al., 2001; Holowka et al., 2002). If the hand activity showed systematic organization, then these forms were further examined to determine whether they had unique organizational properties, or whether the forms shared formational properties with the phonetic and syllabic organization common to signed and spoken languages. To make this more concrete, extreme care was taken not to prejudge a baby's hand form as having sign phonetic (syllabic) status until the frequency and distributional analyses told us that this was warranted. This is similar to the way that much care is taken not to prejudge a hearing baby's acoustic vocalization as being a "babble" without a combination of evidence—including evidence from frequency and distributional analyses that a specific vocalization is indeed a phonetic unit (in syllabic organization; Oller & Steffens, 1994).

Finally, if a sign-phonetic unit was identified, attribution of "manual babbling" status to this hand activity was done by adhering to the strict set of standard criteria used for decades in attributing vocal babbling status to the vocalizations of hearing babies (e.g., Elbers, 1982; Locke, 1983; Oller & Eilers, 1988), and that were used by Petitto & Marentette (1991), and, as stated above, includes three hallmark characteristics: Forms must (i) be produced with a reduced subset of combinatorial units that are members of the phonetic inventory of all natural languages, (ii) demonstrate the syllabic organization seen only in natural languages (which inherently involved reduplication), and (iii) be produced without meaning or reference. If a hand form met these three criteria, it was coded as *babble*. All other forms were coded as *non-babble*. Taken together, this video transcription system enabled us to investigate *qualitatively* the different types of hand activity produced by all of the babies relative to the *quantitative* analysis of rhythmic frequency provided by the Optotrak technology.

To further understand the linguistic versus non-linguistic nature of the hand activity produced by all babies, a "location-in-space" analysis was performed. We were curious about this because in signed languages one striking index that a hand activity is linguistic (as opposed to non-linguistic) is that it must occur within a highly restricted space in front of the signer's body that is bound by strict rules of the grammar of the sign language; indeed, hand activity falling outside of these obligatory linguistic spaces are judged to be either non-linguistic gestures or simply not in the language (ungrammatical). Each movement segment was assigned a location in egocentric, or body-centered, space in consultation with the videotaped data. Raters who were blind to the babies' group assignments and who did not know sign language, coded the location of the babies' hand activity in space. To ensure objective coding, each rater was given a visual template of a young human form in four divisions vertically and laterally (from top to bottom; side to side) that provided locations by number with named anatomical landmarks, which only the experimenters knew also corresponded to established obligatory linguistic spatial constraints of sign language, especially ASL (Klima & Bellugi, 1979; Neidle, et al., 2000) and LSQ (Bourcier & Roy, 1985; Petitto, Charron & Brière, 1990): Location 1 was the space between the top of the baby's head and the shoulders, Location 2 the space between the baby's shoulders and the chest at the lower margin of the sternum (xiphoid compress; vertically) and from center chest to the length of an extended bent elbow (laterally; this is the linguistically "unmarked" or most used/canonical adult "signing space" and the signing space acquired first and used most frequently by young children acquiring sign languages; see Conlin, Mirus, Mauk, & Meier, 2000; Petitto, 1987), Location 3 the space between the baby's lower margin of the sternum and waist (crest of the iliac), and Location 4 the space below the waist (crest of the iliac). For statistical purposes, the 400 movement segments were then coded as falling either within the *sign-*

space (Location 2) or outside of the signing space (Locations 1, 3, 4), which was coded as *non sign-space*. Hand activity that crossed all four locations in space (i.e., large waving motions of the hand and arm) was excluded from the analysis, and constituted 47% (188/400) of the corpus.

Reliability measures. Inter-rater reliability measures were taken on all aspects of the procedure. One rater performed the Optotrak analyses, which yielded frequency values for 400 movement segments. Reliability tests were then performed on all 400 movement segments by one rater, and a second independent rater conducted reliability tests on random samples of this corpus. Similarly, all 2082 movement segments captured on videotape were transcribed once by a single rater. The 400 movement segments that were randomly sampled and analyzed using the Optotrak technology were also fully transcribed from the videotapes by a second independent rater. Reliability tests were further performed by a third observer on random samples of the 400 movement segments from the videotapes. All conflicts with respect to the coding of all fields were resolved through discussion with agreement reaching 100%.

Results

The analyses yielded both an intriguing similarity and an intriguing difference between the two baby groups: Both speech and sign exposed baby groups were similar in that they produced a *high*-frequency hand activity at around 2.5-3.0 Hertz (by way of one example, a baby who produced roughly 3 complete hand movement cycles per second), which was found to be non-linguistic excitatory hand/arm activity common to all babies at this age. However, the baby groups were different in that only the sign-exposed hearing babies produced an additional class of *low*-frequency hand activity with a unique rhythmic signature of around 1 Hz. Further analyses revealed that this second class of activity was "manual babbling," and was produced largely within the linguistically-constrained signing space. These findings are based on the following analyses.

Optotrak analyses. Analyses of the Optotrak quantitative data provided frequency values in Hertz (Hz) for all 400 movement segments (200 per group) produced by the babies. The distribution of frequency values were then plotted and compared across groups of babies (sign- versus speech-exposed) across all ages (6, 10 and 12 months). As is visible in Figure 1, the sign-exposed babies' frequency values of movement segments were bimodally distributed. The major mode (on left) falls around 1 Hz and the minor mode (on right) falls around 2.5 Hz. In contrast, frequency values of the speech-exposed babies' movement segments were unimodal, with their mode falling around 3 Hz (also right in Figure 1). A comparison of the two groups further revealed that the frequency of the movement segments produced by the sign-exposed babies was significantly different from the activity of the speech-exposed babies at the same ages (χ^2 (20, N = 200) = 389.65, p< .001).

The results obtained through analyses of the Optotrak data provided a quantitative description of the rhythmic hand activity produced by the two groups of babies. The objective measurements of the frequency of the babies' hand activity clearly indicated that the sign-exposed group of babies was producing two distinct types of hand activity. Stated differently, the frequency at which hand activity is performed depends on whether babies are exposed to sign or speech. As only the sign-exposed group of babies was receiving systematic exposure to linguistic stimuli in the manual modality, we had hypothesized that the differences between the two groups of babies could be attributed to manual babbling. It is evident from the distribution of activity illustrated in Figure 1 that only the sign-exposed group of babies produced a low-frequency type of hand activity. We had hypothesized that this activity produced at approximately 1 Hz was manual babbling.

The high-frequency activity produced by both groups of babies, on the other hand, was hypothesized to be the non-linguistic motoric activity akin to that which Thelen (1979, 1991) has described of all normally developing babies. Thus, having discovered solid quantitative differences between the two baby group's hand activity using the Optotrak technology, we turned to the videotaped data to test our hypotheses by visually examining, transcribing, and analyzing the same 400 movement segments produced by the babies.

Videotape analyses. The Optotrak analyses revealed a significant difference between the sign-exposed and speech-exposed babies, a difference which we had hypothesized could be attributed to the sign-exposed babies' production of manual babbles. Based on our knowledge of the vocal babbling literature and on our previous studies of manual babbling (Petitto & Marentette, 1991), we had hypothesized that manual babbling would (i) be observed in babies exposed to sign language, (ii) be produced at a frequency that differed from the frequency of the non-linguistic hand activity that all babies perform as part of normal motor development, (iii) adhere to the well-established babbling criteria (both oral and manual), and (iv) show other indices of being linguistically constrained, for example, being produced within the adult linguistic "signing space." The Optotrak analyses were suggestive with regards to points (i) and (ii), and thus we explored the two remaining criteria to better understand the nature of the group differences.

Through the Optotrak analyses, we learned that only the sign-exposed babies had manual activity that was bimodally distributed (with respect to the speed of their movements). To provide insight into the nature of the manual activity produced by the sign-exposed babies across all ages, we therefore needed to partition the observed movement speeds (or frequencies) into their respective low- and high-frequency modes. To do this, we used a classification algorithm, a K-Means Cluster Analysis, which assigned each individual movement segment produced by the sign-exposed babies into categories. The K-Means Cluster Analysis isolated homogeneous groups of cases (based on frequency, that is, speed of movement), and an iteration process maximized fit. The algorithm defined two categories (clusters) of movement segments produced by the babies (again, based on the speed of their movements). The first cluster identified by the K-Means Analysis (i.e., the babies' "low-frequency" activity) contained 52% of the babies' total activity. The second cluster identified by the K-Means Analysis consisted of the remaining 48% of the movement segments produced by the babies (i.e., the babies' "high-frequency" activity).

Using the low- and high-frequency clusters defined by the K-Means Analysis, we evaluated the final two points of our criteria for manual babbling to shed light on the nature of the movement segments produced by the sign-exposed babies. Specifically, we were interested in determining whether any of the movement segments observed in the low-frequency cluster were coded as "babbles" from the videotape analyses, and whether any activity was produced in the adult linguistic "sign-space" (points iii and iv respectively of our criteria for manual babbles). We therefore matched every instance of "babble" and every instance of activity produced in the linguistic "sign-space," with its corresponding frequency value (the speed at which these movements were produced), and hence, its corresponding low- or high-frequency cluster determined by the K-Means Analysis. The results are presented for each sign-exposed baby individually, for the group as a whole, at each experimental age, and across all ages (as in the Optotrak analyses; see Table 3). Each baby will be discussed in turn.

A striking aspect of the data from Table 3 is that approximately 80% of the babies' low-frequency activity were babbles and produced in the sign-space. This overall pattern holds for all three babies, at each experimental session, and across all ages. The movement segments produced by Baby E1 coded as "babble" or as falling within the "sign-space," for example, are plotted in Figure 2 relative to the total distribution of movement segments (in Hertz) produced. Across the three ages tested, 69% of Baby E1's manual activity was coded as babble, and 77% was produced within the linguistic sign-space. In contrast, only 17% and 25% of the high-frequency activity produced was determined to be a manual babble or produced in the sign-space respectively. Moreover, little variation in this overall pattern was observed at each individual age (between 60% and 75% of the low-frequency activity produced from 6 to 12 months was coded as a babble, and between 75% and 80% as falling within the sign-space, whereas only 0-20% of the high-frequency activity were babbles, and 0-30% were produced in the sign-space; Table 3).

Similarly, Baby E2 produced a remarkable amount of babbles, and activity in the sign-space at a low-frequency across all ages (94% and 90% respectively; Figure 3), and these percentages ranged only from 93-100% from ages 6 to 12 months for babbles, and from 90-100% for low-frequency activity produced in the sign-space. As is evident from

Figure 3, baby E2 produced few babbles at a high-frequency (32% overall), and few high-frequency movement segments were produced in the sign-space (21% overall). Again, these findings held at each individual age (between 0-39% babbles, and between 0-23% sign-space activity were produced from 6 to 12 months).

Finally, the breakdown of activity coded as a manual babble or as being produced in the sign-space for Baby E3 are presented in Figure 4. On average 90% of Baby E3's activity produced at a low-frequency was coded as a babble, and 81% was produced in the sign-space. From 6-12 months these percentages varied between 67-100% for Baby E3's production of babbles and activity produced in the sign-space at a low frequency. Few babbles (24% overall; 0-27% from 6-12 months) and few movement segments occurring in the sign-space (32% overall; 0-36% from 6-12 months) were produced by Baby E3 at a high frequency.

Unlike the sign-exposed babies, the speech-exposed babies produced manual activity that was normally distributed across all babies, across all ages (recall Figure 1). As such, a classification algorithm similar to the K-Means Cluster Analysis applied to the sign-exposed babies' data, was unnecessary here. Moreover, none of the activity produced by the speech-exposed babies was coded as babble from the videotapes, and only 8% of all of the speech-exposed babies' activity was coded as falling within the linguistic sign-space. While our video analyses, and strict criteria for attributing babbling status to manual activity, revealed that none of the activity produced by the speech-exposed babies were babbles, clearly some activity produced by the speech-exposed babies was produced at a low frequency, as was determined through the Optotrak analyses. This low-frequency activity was observed in the original figure of the two groups of babies' distributions of hand-movement frequency (Figure 1; the overlapped activity falling below approximately 2 Hz). An hypothesis as to the nature of this low-frequency activity observed in the speech-exposed babies is presented in the Discussion.

In sum, we discovered through the "blind," quantitative Optotrak analyses that only the sign-exposed babies produced hand movement segments that were bimodally distributed with respect to the speed of their movements. The plot of the frequency (speed) at which the sign-exposed babies produced these movement segments, revealed both visually and statistically a significant difference between the sign-exposed and speech-exposed groups of babies. Of the two modes observed in the bimodal distribution of the sign-exposed babies' manual activity, one was characterized by a low speed of hand movements (i.e., low-frequency activity produced at approximately 1 Hz) relative to the higher speed of hand movements (i.e., high-frequency activity produced around 2.5-3.0 Hz). Moreover, the high-frequency activity produced by the sign-exposed babies was not unlike the unimodal distribution of speed of hand movements produced by the speech-exposed babies (i.e., high-frequency activity produced at approximately 3 Hz). To investigate the nature of these low- and high-frequency modes, we first used the K-Means Cluster Analysis to partition the bimodal distribution of the movement segments produced by the sign-exposed babies into either the "low-frequency" or "high-frequency" categories. The K-Means Analysis was unwarranted in the case of the speech-exposed babies, however, as their data were unimodal. We then turned to standard videotape analyses to determine whether any of the low- or high-frequency activity (as determined by the K-Means Analysis) produced by the sign-exposed babies, or whether any of the speech-exposed babies' activity was coded as babbles or produced within the linguistic sign-space. Overall, it was determined that approximately 80% of the sign-exposed babies' low-frequency (speed) activity was manual babbling, and was constrained to the linguistic sign-space. In contrast, the sign-exposed babies' high-frequency activity was largely non-linguistic in that only approximately 25% were coded as babbles and as falling within the sign-space. This latter class of activity was akin to the high-frequency hand movements produced by the speech-exposed babies, in that no activity was coded as babble and only 8% of their movement segments fell within the sign-space. Thus, collectively, our hypotheses that manual babbling would (i) be observed only in babies exposed to a signed language, (ii) be produced at a frequency distinct from that of all normally developing motor activity, (iii) adhere to the criteria for attributing babble status to babies' forms, and (iv) be constrained to the adult, linguistic sign-space, were confirmed through combining the innovative Optotrak technique with the well-established videotape method.

Discussion

To understand the origins of the human language capacity, scientists have turned to clues provided by the regular onset and structure of baby babbling. Yet the biological basis of baby babbling has been debated for decades, with one hypothesis about the origins of babbling (including language acquisition, and language origins) being that it begins as a purely non-linguistic motor activity tied to the opening and closing of the mouth and jaw (Locke, 2000; MacNeilage & Davis, 2000; Studdert-Kennedy, 1991). By contrast, others have offered that babbling is a linguistic activity reflecting the babies' sensitivity to specific patterns at the heart of human language and, in turn, their natural propensity to produce them (de Boysson-Bardies & DeBevoise, 1999; Jusczyk, 1997; Petitto, 1993, 2000; Vihman, 1996); see especially Pinker and Bloom (1990), regarding the possible utility and evolutionary significance of positing a contemporary brain with sensitivity to the grammatical patterns of natural language (see also Rizzolatti & Arbib, 1998).

In pursuit of the strongest possible test of these two hypotheses we studied three hearing babies acquiring spoken language and a remarkable group of three hearing babies acquiring only sign language (no speech). Petitto & Marentette (1991) had previously compared hearing and deaf babies, discovering babbling on the hands of deaf babies only, but differences may have resulted from the two group's radically different sensory experiences. Here, however, the two groups of hearing babies were equal in all developmental respects, but differed only in the form of the language input—by hand or by mouth.

Both groups of babies can and do hear. Both groups of babies can and do make vocal productions. If early human language acquisition is determined exclusively by the maturation and control of the mouth and jaw muscles, then what these two groups of babies do with their hands should be irrelevant; the two groups of babies should have produced fundamentally similar hand activity. Said another way, we would not expect to see any differences in these two groups of babies' hands (despite one receiving sign language input) because this does not involve the mouth and, again, it is mouth motor development that presumably functions like the "master switch" that drives early language acquisition.

But what if there were more to acquiring language – more than the development of the peripheral control of the mouth and jaw? What if the brain possessed tissue specialized to detect specific patterns in the input that initially correspond to key aspects of the grammatical patterning of natural language (Petitto, 1993, 2000; Petitto et al., 2001)? Here, the young hearing baby equipped with this sensitivity should perceive these key patterns coming in on its caretakers' hands and attempt to produce them. This would be so even though the patterns were expressed and received in a way that had nothing to do with the mouth and jaw. In this extraordinary situation, their baby hands should show us differences in the way that they use their hands for linguistic versus non-linguistic activity and, further, their use of hands for linguistic activity should be different from anything seen in hearing babies acquiring speech. At the same time, one component of their use of hands should be similar to what all babies do because, as a developing human organism, there is no reason to expect that they would not exhibit the typical developmental milestones of motor growth.

In the present study, this is precisely what we discovered, and in a novel way. The application of the Optotrak technology to study early linguistic development enabled us to examine the frequencies at which hearing babies exposed to signed and spoken languages produce their rhythmic hand activity. Here we discovered that the hearing babies acquiring sign produced two distinct types of rhythmic hand activity: One type of low-frequency activity was produced at approximately 1 Hz, and one type of high-frequency activity was produced at approximately 2.5 Hz. We also discovered that the hearing babies acquiring speech produced only one class of high-frequency hand activity at approximately 3 Hz, and that this was fundamentally similar to the sign-exposed babies' high-frequency hand activity. The Optotrak technology thus provided the first quantitative measurement of babies' rhythmic hand activity in pursuit of fundamental linguistic questions.

Next we turned to qualitative analysis of the videotaped data to examine the precise nature of the low- and high-frequency activity produced by our babies. These analyses revealed that the low-frequency activity was indeed "manual babbling" (Petitto & Marentette, 1991), was produced within the rule-governed obligatory signing space, and was only produced by the sign-exposed babies.

The present findings therefore fail to confirm the ubiquitous motoric hypothesis of baby babbling as well as its application to accounts of early language acquisition and the basis for the evolutionary origins of language. MacNeilage and Davis (2000) argue that language evolved (language phylogeny) due to the affordances provided by the biomechanical properties of the jaw, which, in turn, suggests that speech *determines* the emergence of early language production in ontogeny. Remarkably, and without relying on the mouth, we observed that hearing babies acquiring sign produced manual babbling that was conveyed on their hands with a different class of movement frequencies from the frequencies of their non-linguistic hand activity. This finding is indeed noteworthy because the movement frequencies that distinguished between linguistic and non-linguistic hands were carved out of a single manual modality and yielded two classes of behavior in sign-exposed babies (whereby 52% were low-frequency babbling and 48% was high-frequency non-linguistic hand activity); by contrast, the hearing speech-exposed babies produced their high-frequency activity nearly 100% of the time (with only a fraction of their high-frequency hand activity falling within the low frequency mode). Therefore, we suggest that the present findings provide strong support for the linguistic hypothesis of babbling and by extension human language acquisition. That the linguistic and non-linguistic hand movements were robustly differentiated by distinct rhythmic frequencies could only have resulted if babies find salient and can use the specific rhythmic patterns that underlie natural language[3].

Clearly motoric development contributes to the production of syllabic babbling in both the manual and vocal modalities in some capacity, but not in the exclusive way that MacNeilage and Davis (2000) and Locke (2000) have proposed. If this were the case, then linguistic babbling should *not* have been present in the manual mode in our hearing babies acquiring sign (nor deaf babies acquiring sign; Petitto & Marentette, 1991). But if a strictly motoric explanation cannot account for the onset of human language production, then what is guiding the convergence of linguistic structure across both the signed and spoken modalities?

We propose an alternative account of babbling that has implications for the origins of language in babies, one which integrates both linguistic and motor control principles. Ours is a view consistent with the linguistic hypothesis of babbling above, which suggests that babbling makes possible the baby's discovery and production of the most rudimentary structures of natural language, phonetic-syllabic units (e.g., de Boysson-Bardies, 1993; de Boysson-Bardies & DeBevoise, 1999; Jusczyk, 1986, 1993, 1997; Vihman, 1996). Here, however, we hope to take this notion farther by articulating how the baby might discover the core syllabic babbling unit in the first place. What appeared to differentiate non-linguistic hand activity from manual babbling in the present study was the unique *rhythmic signature* of natural language (as compared to non-linguistic activity). An hypothesis that we are testing further is that sign-exposed babies are initially sensitive to rhythmic bursts of about 1 Hz and all linguistic units that fall within it. This, then, would afford babies with the means to discover the particular babbling segments that they will produce in the first place. Further, the specific rhythmic and reduplicated act of babbling may reflect the neurological integration of the motor production systems and the mechanisms sensitive to specific rhythmic signatures unique to natural language.

It does not follow from our finding that because sign-exposed babies produced linguistic manual babbling at 1 Hz that speech-exposed babies should also produce vocal babbling at 1 Hz. (Nor does it follow that sensitivity to 1 Hz frequency in the sign-exposed babies should remain stable across all of early development.) We fully expect modality differences to yield Hz/frequency differences. The most crucial generalization that we wish to advance, however, is that frequency differences between linguistic and non-linguistic input exist both in the speech and in the sign stream (regardless of the input modality)—even though we may find that the absolute frequency varies from one modality to the next, and, crucially, that all human babies are born sensitive to them. In other words, we are suggesting here that these frequency differences are highly constrained and patterned and that all young babies are tacitly sensitive to this information. It is what the baby uses to discover the phonetic and syllabic segments in the linguistic stream so as to produce babbling in the first place and, ultimately, to crack-the-code of its native language's structure.

To summarize more generally how language acquisition might have proceeded in the present case, the young hearing baby exposed to sign language, equipped with such a sensitivity to specific rhythmic frequency patterns, would perceive these key patterns coming in on its caretakers' hands. Then, building on pre-existing *multiple* neural pathways to the primary motor cortex (hand, mouth, oral-facial), the baby would attempt to produce these nascent patterns beginning around age 6 months mirroring the specific modality to which the patterns were inputted/perceived. Here, we propose that it is the human child's sensitivity to specific rudimentary rhythmic patterns that correspond to aspects of natural language structure that is genetically endowed and stable across the species, and that this sensitivity is one of the primary "master-switches" that launches and determines the universal developmental language milestones that we see in the first year of life such as babbling. On this view, the human capacity to *express* language constitutes a neurologically "open" genetic program at birth, with its neural "stabilization" only coming "on-line" in the first few months of life. This expressive capacity is initially so highly "plastic" that, as has been shown in the present study (and a generation of others, e.g., see Petitto, 2000, for a review), it can recruit "on-line" either the hands or the tongue without any loss, delay, or trauma to the timing and the achievement of the normal language acquisition milestones. Thus, rather than mouth-jaw motor developments driving all of early human language ontogeny the most radical proposal being offered here is that the human expressive capacity is not neurological "fixed" at birth and instead develops and becomes neurologically fixed only *after* birth in all humans (actually, this always seemed self-evident to us if only on the grounds that we all agree that babies are not born talking). We shall leave for others to address the evolutionary (phylogenetic) significance of our proposal regarding human language ontogeny and its implication that aspects of the need to process rapidly densely-packed, complex, and *multisensory* input signals could have given rise to a brain that had the capacity to extract away from the raw input modality to the detection of its underlying key patterns—and, with regard to human language—its key underlying grammatical units and their distributional regularities—which could have ultimately afforded selection advantages for successive communication and social organization.

A final puzzle is this: Do hearing babies acquiring spoken language produce manual babbling as seen in babies acquiring sign languages? No. But they do produce rhythmic hand activity, and the present study teaches us that all rhythms are not the same. The Optotrak analyses showed us that the rhythmic frequencies underlying true manual babbling in sign-exposed babies was different from the rhythmic frequencies underlying non-linguistic hand activity in speech-exposed (and sign-exposed) babies.

This leads us to a key methodological point: Although syllabic organization was observed in the Petitto and Marentette study (1991), nothing was known about the precise rhythmic frequency of manual babbling. For this reason, the precise definition of manual babbling has been subject to controversy and, as such, has eluded researchers thus far. Now Optotrak analyses of rhythmic hand activity provide the quantitative aspect of the definition lacking in previous studies, and we suggest that use of technology such as Optotrak is imperative in all such future studies. Recall that previous attributions about the existence of manual babbling in hearing babies acquiring *spoken language* relied exclusively on subjective decisions made after looking at videotapes of babies' hands (Meier & Willerman, 1995). But this method alone will not do because use of the Optotrak teaches us that there are crucial quantitative data to be discovered that are not possible to obtain with a videotape alone. It would be like trying to *see* the difference between [p] and [b] on a videotape alone without a speech spectrogram. In moving away from the exclusive use of videotapes, we will remove the confusion caused in the literature by subjective coding procedures, and we will alleviate the confusion over various definitions of manual babbling (see Meier & Willerman, 1995; Cormier et al., 1998). Finally, we will remove speculations about the existence of manual babbling in hearing babies acquiring spoken language because, again, it does not occur both in the way and to the extent that have been claimed (see Meier & Willerman, 1995). That young hearing babies acquiring speech do occasionally hit upon true syllabic *manual* babbles is identical to the phenomenon whereby young deaf babies do occasionally hit upon true syllabic *vocal* babbles (Oller & Eilers, 1988; more below). Some of this overlap is due to accidental production affordances inherent in the respective hand-mouth modalities and, crucially, some of it is wholly predicted by the hypothesis we propose here (as well as in Petitto & Marentette, 1991 and Petitto, 1993, 2000).

Why do hearing babies acquiring speech (no sign) produce some occasional and highly reduced instances of manual babbling-type activity on their hands? Petitto (1993) offered a linguistically-based alternative hypothesis as to why hearing babies may produce instances of babbling on their hands, one which also explains how it is possible that profoundly deaf babies can produce instances of vocal babbling. Drawing from the robust similarities between the phonetic and syllabic content of vocal and manual babbling, Petitto hypothesized that the human brain contains specialization to particular input patterns relevant to aspects of the structure of natural language that is linked to rudimentary motor programs to produce them--but that is not initially linked to a particular modality. If so, it follows that speech and manual movements in young babies are *equipotential* articulators, either of which can be recruited "on-line" in very early development, depending upon the language and modality to which the baby is exposed. It further follows that a baby's "alternative" modality--or the modality in which the baby is not receiving linguistic input--may evidence this equipotentiality in the form of motoric "leakage," whereby it may run off in unsystematic ways relative to the baby's corresponding systematic and patterned productions of babbling. As support for this hypothesis, Petitto and Marentette (1991) found through qualitative analyses that although a small portion of their hearing (non-sign exposed) babies' manual activity was indeed like that of deaf babies' manual babbling, it contained far fewer phonetic units (3 as compared to 13 in the deaf babies), with far fewer and less complex syllabic organization (1 as opposed to 4 syllable types in deaf babies). Interestingly, the nature of deaf babies' vocal babbling further supports this hypothesis: In addition to deaf babies' systematic hand babbling, deaf babies also produce syllabic vocal babbling, but, here, their vocal syllables exhibit a very reduced set of consonants and vowels with very little variation in syllabic form (Oller & Eilers, 1988; see also Footnotes 2 and 3).

The Optotrak analyses of the babies' rhythmic manual activity in the present study also showed us that some activity in the hearing babies acquiring speech "appeared" to be manual babble-like, in that it carried the same low-frequency rhythmic signature. But this babble-like activity was unsystematic in linguistic form, as revealed by the application of the babbling criteria to the babies' forms, and was further unprincipled as revealed by the location in space analyses. Thus, the systematic and patterned manual babbling observed only in the sign-exposed hearing babies on the other hand, was one constrained by linguistic principles, as revealed through the following three powerful defining features: their low-frequency movement cycles, the stringent criteria for attributing babbling status to babies' early forms, and the babies' production of this activity in the obligatory signing space—three features which together constitute the best definition of manual babbling by which to judge all other hand activity.

Through the unique lens of an extraordinary population of hearing babies acquiring sign language, we discovered that the rhythmic frequencies of their hands differed depending on whether they were producing linguistic versus non-linguistic activity. Surprisingly, without benefit of the mouth, these hearing babies babbled on their hands. This finding fails to support the hypothesis that human babbling (and hence early human language acquisition) is exclusively determined by the baby's emerging control over the mouth and jaw. Instead, it suggests the hypothesis that the differentiation between linguistic and non-linguistic hand activity could only have resulted if all babies are born with a sensitivity to specific rhythmic patterns at the heart of human language and a capacity to use them. This further lead to our proposing a new hypothesis to explain the emergence of early language that most certainly warrants much additional research. At the same time, we hope to have shown that by investigating the basis of babbling from the perspective of another modality, we can finally begin to discern the relative contribution of biological and environmental factors that together make possible the ontogeny of human language.

Footnotes

1. Like spoken languages, all signs (homologous to the words) and sentences in sign languages are formed from a restricted/finite set of meaningless units called sign-phonetic units (e.g., Brentari, 1999; e.g., the unmarked, frequent phonetic unit in American Sign Language involving a clenched fist with an extended thumb), which are further organized into syllables. Like the consonant-vowel syllable structure in spoken language, the structural nucleus of the "sign-syllable" consists of the rhythmic opening and closing alternations and/or the rhythmic movement-hold alternations of the hands/arms (e.g., Liddell & Johnson, 1989; Perlmutter, 1991, 1992).

2. These hearing babies were raised entirely immersed in an highly exclusive signing deaf world (with deaf parents and deaf extended family members, all of whom were active in weekend local deaf social clubs, etc.) from birth until approximately age 3. To be sure, all of these sign-exposed hearing babies were immersed in this signing deaf context well within the key time period relevant to the present study, ages 6 to 12 months. While the babies would not have heard the radio or television (as no audio would be present in a deaf home), these hearing babies must have heard some speech; for example, at a gas station or in a supermarket. However, no baby in this study received *systematic* exposure to any spoken language and certainly none had spoken language systematically directed to them; although both points are important, systematic exposure within key

maturational time periods of human development is utterly crucial in human language acquisition. Furthermore, one example that this extremely occasional speech was not salient to and/or used by these babies is the fact that they did not produce *systematic* syllabic vocal babbling, and they should have if they were attending to/analyzing this overheard speech (see Footnote 3).

3. Interestingly, the motoric hypothesis, with its focus on the emerging control over the mouth and jaw, would also predict that both baby groups should have babbled *vocally*. As growing young humans, by default, both groups of babies were developing more and more control over their mouth and jaw muscles—just like both groups of babies were developing the abilities to sit, stand, and walk. But our hearing babies acquiring sign did not vocally babble like other hearing babies, thereby providing a further challenge to the motoric hypothesis. Although beyond the scope of the theoretical goals of this paper, our hearing babies exposed only to sign language did of course produce vocalizations and at times they even hit upon a syllabic *vocal* babble. But these babies' vocal babbling was distinctively "off," different from a baby who receives systematic exposure to speech. Their vocal babbling was not systematic in the way seen in other hearing babies acquiring speech, did not contain the normal range of phonetic units and syllable types and the onset times and babbling progression were different from the regular patterns typically seen (for corroborating evidence see also Oller & Eilers, 1988). Precisely how our sign-exposed hearing babies' vocal babbling was different (and

similar) to the babbling of hearing babies receiving systematic speech input is presently under investigation. As we suggest below, these hearing babies acquiring sign do not vocally babble like other hearing babies because they are not receiving the patterned language input that they need (in this case, in speech) to initiate the language analysis-babbling loop. Although these babies do hear sounds and fragments of speech, they teach us that fragmentary and unsystematic input is, evidently, just not enough. They need systematic exposure to the specific patterns found in natural language (in this case, spoken language); what they do with the fragmentary speech input can only go so far—especially here with regard to their absence of normal vocal babbling and in general with regard to how much of language any child can construct without formal systematic patterned input (e.g., Goldin-Meadow, 1981).

References

Brentari, D. (1999). *A prosodic model of sign language phonology.* Cambridge, MA: MIT Press.

Boucier, P., & Roy, J. E. (1985). La langue des signes (LSQ). *Bibliothèque Nationale du Québec*. Dordrecht: Kluwer Academic.

Conlin, K. E., Mirus, G. R., Mauk, C., & Meier, R. P (2000). The acquisition of first signs: Place, handshape, and movement. In C. Chamberlain & J. P. Morford (Eds.), *Language acquisition by eye* (pp. 51-69). Mahwah, NJ: Lawrence Erlbaum & Associates.

Cormier, K., Mauk, C., & Repp, A. (1998). Manual babbling in deaf and hearing babies: A longitudinal study. In E. Clark (Ed.), *Proceedings of the child language research forum, 29*, 55-61. Stanford, CA: CSLI Press.

Davis, B. L., & MacNeilage, P. F. (1995). The articulatory basis of babbling. *Journal of Speech and Hearing Research, 38* (6), 1199-1211.

de Boysson-Bardies, B. (1993). Ontogeny of language-specific syllabic productions. In B. de Boysson-Bardies, S. de Schonen, P. Jusczyk, P. MacNeilage, & J. Morton (Eds.), *Developmental neurocognition: Speech and face processing in the first year of life* (pp. 353-363). Dordrecht: Kluwer Academic.

de Boysson-Bardies, B., & DeBevoise, M. (1999). *How language comes to children: From birth to two years.* Cambridge, MA: MIT Press.

Elbers, L. (1982). Operating principles in repetitive babbling: A cognitive continuity approach. *Cognition, 12* (1), 45-63.

Goldin-Meadow, S. (1981). Fragile and resilient properties of language learning. In E. Wanner & L. R. Gleitman (Eds.), *Language acquisition: state of the art.* Cambridge, England: Cambridge Univeristy Press.

Holowka, S., Brosseau-Lapré, F., & Petitto, L. A. (2002). Semantic and conceptual knowledge underlying bilingual babies' first signs and words. *Language Learning, 52* (2), 205-262.

Jusczyk, P. W. (1986). Toward a model of the development of speech perception. In J. Perkell & D. H. Klatt (Eds.), *Invariance and variability in speech processes* (pp. 1-35). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Jusczyk, P. W. (1993). Sometimes it pays to look back before you leap ahead. In B. de Boysson-Bardies, S. de Schonen, P. Jusczyk, P. MacNeilage, & J. Morton (Eds.), *Developmental neurocognition: Speech and face processing in the first year of life* (pp. 227-236). Dordrecht: Kluwer Academic.

Jusczyk, P. W. (1997). *The discovery of spoken language.* Cambridge, MA: MIT Press.

Klima, E. S., & Bellugi, U. (1979). *The signs of language*. Cambridge, MA: Harvard University Press.

Liddell, S., & Johnson, R. (1989). American Sign Language: The phonological base. *Sign Language Studies, 64,* 195-278.

Lieberman, P. (2000) *Human Language and our reptilian brain: The subcortical bases of speech, syntax, and thought*. Cambridge, MA: Harvard University Press.

Locke, J. L. (1983). *Phonological Acquisition and Change.* New York: Academic Press.

Locke, J. L. (1990). Structure and stimulation in the ontogeny of spoken language. *Developmental Psychobiology, 23*, 621-644.

Locke, J. L. (2000). Movement patterns in spoken language. *Science, 288*, 449-451.

Locke, J. L., Bekken, K. E., McMinn-Larson, L., & Wein, D. (1995). Emergent control of manual and vocal-motor activity in relation to the development of speech. *Brain and Language, 51*, 498-508.

Locke, J. L., & Pearson, D. M. (1990). Linguistic significance of babbling: Evidence from a tracheostomized baby. *Journal of Child Language, 17*, 1-16.

MacNeilage, P. F. (1998). The frame/content theory of evolution of speech production. *Behavioral and Brain Sciences, 21* (4), 499-546.

MacNeilage, P. F., & Davis, B. L. (2000). On the origin of internal structure of word forms. *Science, 288,* 527-531.

Mehler, J., Lambertz, G., Jusczyk, P., & Amiel-Tison, C. (1986). Discrimination of the mother tongue by newborn babies. *Comptes-rendu de l'Académie des Sciences de Paris, 303, Série III* (15), 637-640.

Meier, R. P. (1997). Silent mandibular oscillations in vocal babbling. *Phonetica, 54,* 153-171.

Meier, R. P., Mauk, C., Mirus, G. R., & Conlin, K. E. (1998). Motoric constraints on early sign acquisition. In E. Clark (Ed.), *Proceedings of the child language research forum, 29* (pp. 63-72). Stanford, CA: CSLI Press.

Meier, R. P., & Willerman, R. (1995). Prelinguistic gesture in deaf and hearing babies. In K. Emmorey & J. S. Reilly (Eds.), *Language, gesture and space* (pp. 391-409). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Neidle, C., Kegl, J., MacLaughlin, D., Bahan, B., & Lee, R. J. (2000). *The Syntax of American Sign Language*. Cambridge, MA: MIT Press.

Oller, D. K., & Eilers, R. E. (1988). The role of audition in baby babbling. *Child Development, 59* (2), 441-449.

Oller, D. K., Eilers, R. E., Bull, D. H., & Carney, A. E. (1985). Prespeech vocalizations of a deaf baby: A comparison with normal metaphonological development. *Journal of Speech and Hearing Research, 28,* 47-63.

Oller, D. K., & Steffens, M. L. (1994). Syllables and segments in baby vocalizations and young child speech. In M. Yavas (Ed.), *First and second language phonology* (pp. 45-61). San Diego: Singular Publishing Group.

Ostry, D. J., Vatikiotis-Bateson, E., & Gribble, P. L. (1997). An examination of the degrees of freedom of human jaw motion in speech and mastication. *Journal of Speech, Language and Hearing Research, 40,* 1341-1351.

Perlmutter, D. (1991). Sonority and syllable structure in American Sign Language. Unpublished paper. Department of Linguistics, University of California, San Diego.

Perlmutter, D. (1992). *Linguistic Inquiry, 23,* 407-442.

Petitto, L. A. (1987). On the autonomy of language and gesture: Evidence from the acquisition of personal pronouns in American Sign Language. *Cognition, 27* (1), 1-52.

Petitto, L. A. (1993). On the ontogenetic requirements for early language acquisition. In B. de Boysson-Bardies, S. de Schonen, P. Jusczyk, P. MacNeilage, & J. Morton (Eds.), *Developmental neurocognition: Speech and face processing in the first year of life* (pp. 365-383). Dordrecht: Kluwer Academic.

Petitto, L. A. (2000). On the biological foundations of human language. In H. Lane & K. Emmorey (Eds.), *The signs of language revisited* (pp. 447-471). Mahwah, NJ: Lawrence Erlbaum & Associates.

Petitto, L. A., Charron, F., & Brière, S. (1990). Etude de la Langue des Signes Québecoise (LSQ). *Technical Reports in Cognitive Science 7*. McGill University, Montréal, Québec, Canada.

Petitto, L. A., Holowka, S., Sergio, L., & Ostry, D. (2001). Language rhythms in baby hand movements. *Nature, 413* (6), page 35-36.

Petitto, L. A., Katerelos, M., Levi, B., Gauna, K. Tetrault, K., & Ferraro, V. (2001). Bilingual signed and spoken language acquisition from birth: Implications for the mechanisms underlying early bilingual language acquisition. *Journal of Child Language, 28*, 453-496.

Petitto, L. A., & Marentette, P. F. (1991). Babbling in the manual mode: Evidence for the ontogeny of language. *Science, 251*, 1483-1496.

Petitto, L. A., Zatorre, R. J., Gauna, K., Nikelski, E. J., Dostie, D., Evans, A. C. (2000). Speech-like cerebral activity in profoundly deaf people processing signed languages: Implications for the neural basis of human language. *Proceedings of the National Academy of Science, 97* (25), 13961-13966.

Pinker, S., & Bloom, P. (1990). Natural language and natural selection. *Behavioral & Brain Sciences, 13* (4), 707-784.

Rizzolatti, G., & Arbib, M. A. (1998). Language within our grasp. *Trends in Neuroscience, 21* (5), 188-194.

Stokoe, W. (1960). Sign language structure: An outline of the visual communication systems of the American Deaf. *Studies in Linguistics, Occasional Papers, 8.*

Studdert-Kennedy, M. G. (1991). A note on linguistic nativism. In R. R. Hoffman & D. S. Palermo (Eds.), *Cognition and the symbolic processes: Applied and ecological perspectives* (pp. 38-58). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Sergio, L. E., & Ostry, D. J. (1995). Coordination of multiple muscles in two degrees of freedom elbow movements. *Experimental Brain Research, 105,* 123-137.

Thelen, E. (1979). Rhythmic stereotypies in normal human babies. *Animal Behavior, 27,* 699-715.

Thelen, E. (1981). Rhythmic behavior in infancy: An ethological perspective. *Developmental Psychology, 17,* 237-257.

Thelen, E. (1991). Motor aspects of emergent speech: A dynamic approach. In N. A. Krasnegor, D. M. Rumbaugh, R. L. Schiefelbush, & M. Studdert-Kennedy (Eds.), *Biological and behavioral determinants of language development* (pp. 339-362). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Van der Stelt, J. M., & Koopmans-van Bienum, F. J. (1986). The onset of babbling related to gross motor development. In B. Lindblom & R. Zetterstrom (Eds.), *Precursors of early speech* (pp. 163-173). New York: Stockton Press.

Vihman, M. M. (1992). Early syllables and the construction of phonology. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications*. Timonium, MD: York Press.

Vihman, M. M. (1996). *Phonological development: The origins of language in the child*. Cambridge, MA: Blackwell Publishers.

Table 1

Ages of Subjects at Videotaped Sessions

	Session		
Group	1	2	3
Sign-Exposed			
E1	0;07.02	0;09.26	1;00.02
E2	0;05.24	0;10.06	1;00.01
E3	0;06.03	0;09.28	1;00.00
Speech-Exposed			
C1	0;06.07	0;10.00	1;00.02
C2	0;05.26	0;10.01	1;00.08
C3	0;06.04	0;09.31	1;00.08

Table 2

Percentage of All Manual Activity Produced by the (a) Sign-Exposed, and (b) Speech-Exposed Babies at 6, 10 and 12 Months

	Age in Months		
Group	6	10	12
(a) Sign-Exposed			
E1	68	16	16
E2	84	10	6
E3	74	23	3
Mean	**75.3**	**16.3**	**8.3**
(b) Speech-Exposed			
C1	78	14	8
C2	72	26	2
C3	79	12	9
Mean	**76.3**	**17.3**	**6.3**

Table 3

Percentage of All (a) Low-Frequency, and (b) High-Frequency Manual Activity Produced by the Sign-Exposed Babies Coded as "Babble" or as Falling Within the Linguistic "Sign-Space," at 6, 10 and 12 Months

	Age in Months							
	6 Months		10 Months		12 Months		All Ages	
(a) Low Frequency	Babble	Sign-Space	Babble	Sign-Space	Babble	Sign-Space	Babble	Sign-Space
E1	60	80	75	75	75	75	69	77
E2	93	90	100	100	100	100	94	90
E3	98	85	67	67	100	100	90	81
Mean	**84**	**85**	**81**	**81**	**92**	**92**	**84**	**82**

(table continues)

	Age in Months							
	6 Months		10 Months		12 Months		All Ages	
(b) High Frequency	Babble	Sign-Space	Babble	Sign-Space	Babble	Sign-Space	Babble	Sign-Space
E1	20	30	0	0	0	0	17	25
E2	39	23	20	20	0	0	32	21
E3	27	32	18	36	0	0	24	32
Mean	**29**	**28**	**13**	**19**	**0**	**0**	**24**	**27**

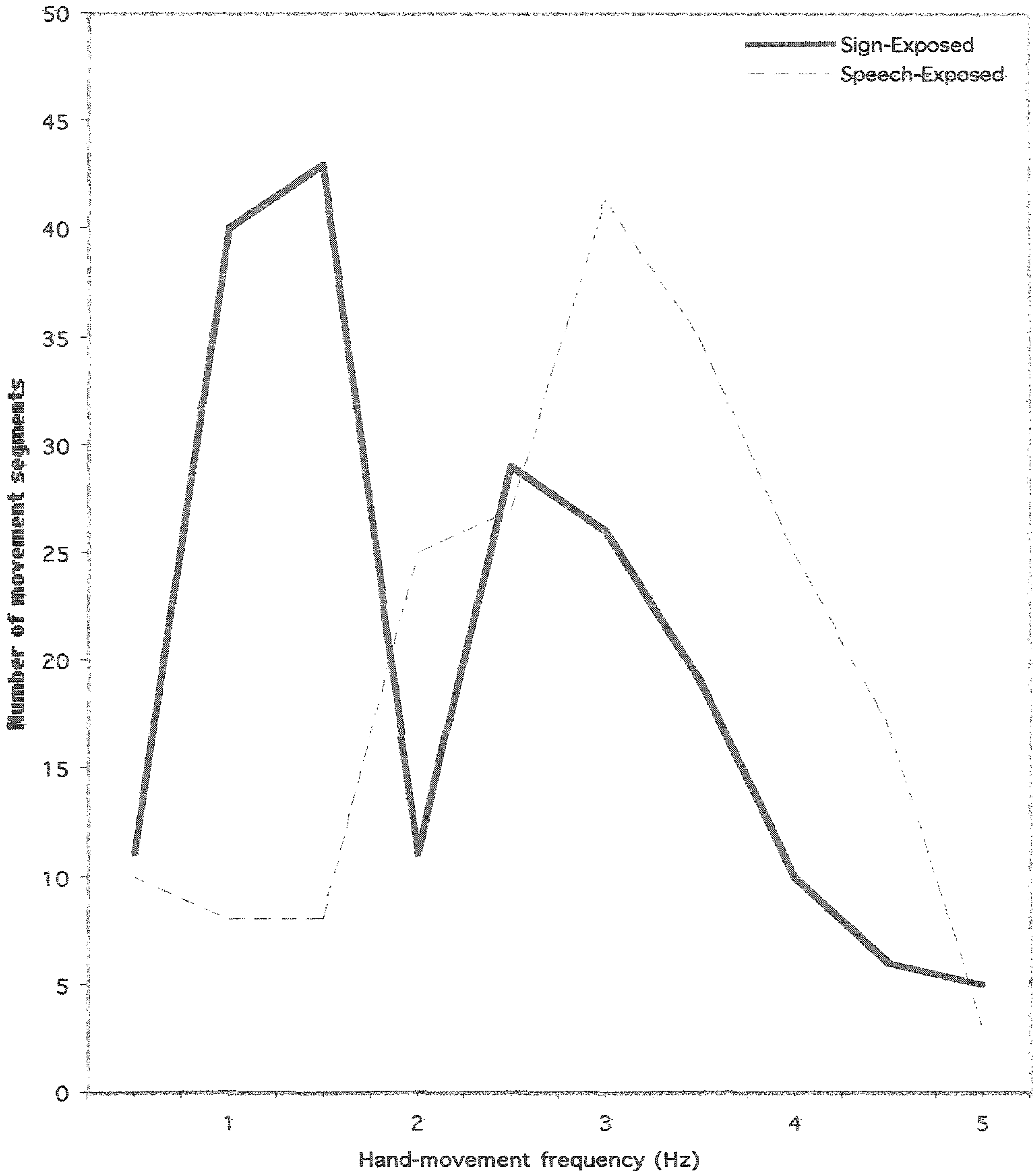

Figure 1

Distribution of the frequencies of sign-exposed and speech-exposed babies' movement segments.

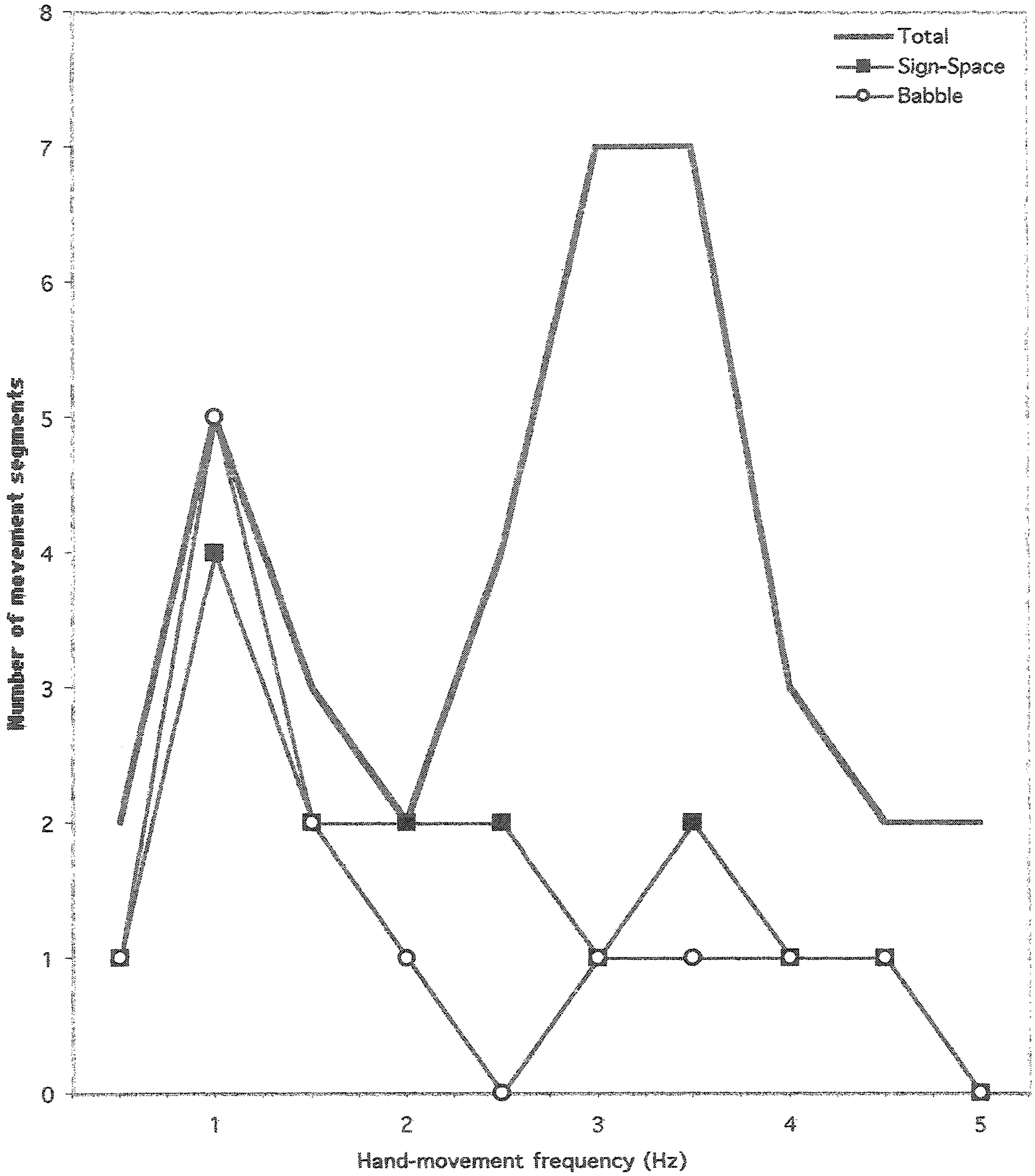

Figure 2

Distribution of the frequencies of sign-exposed baby E1's babbles and sign-space activity relative to the distribution of all movement segments produced.

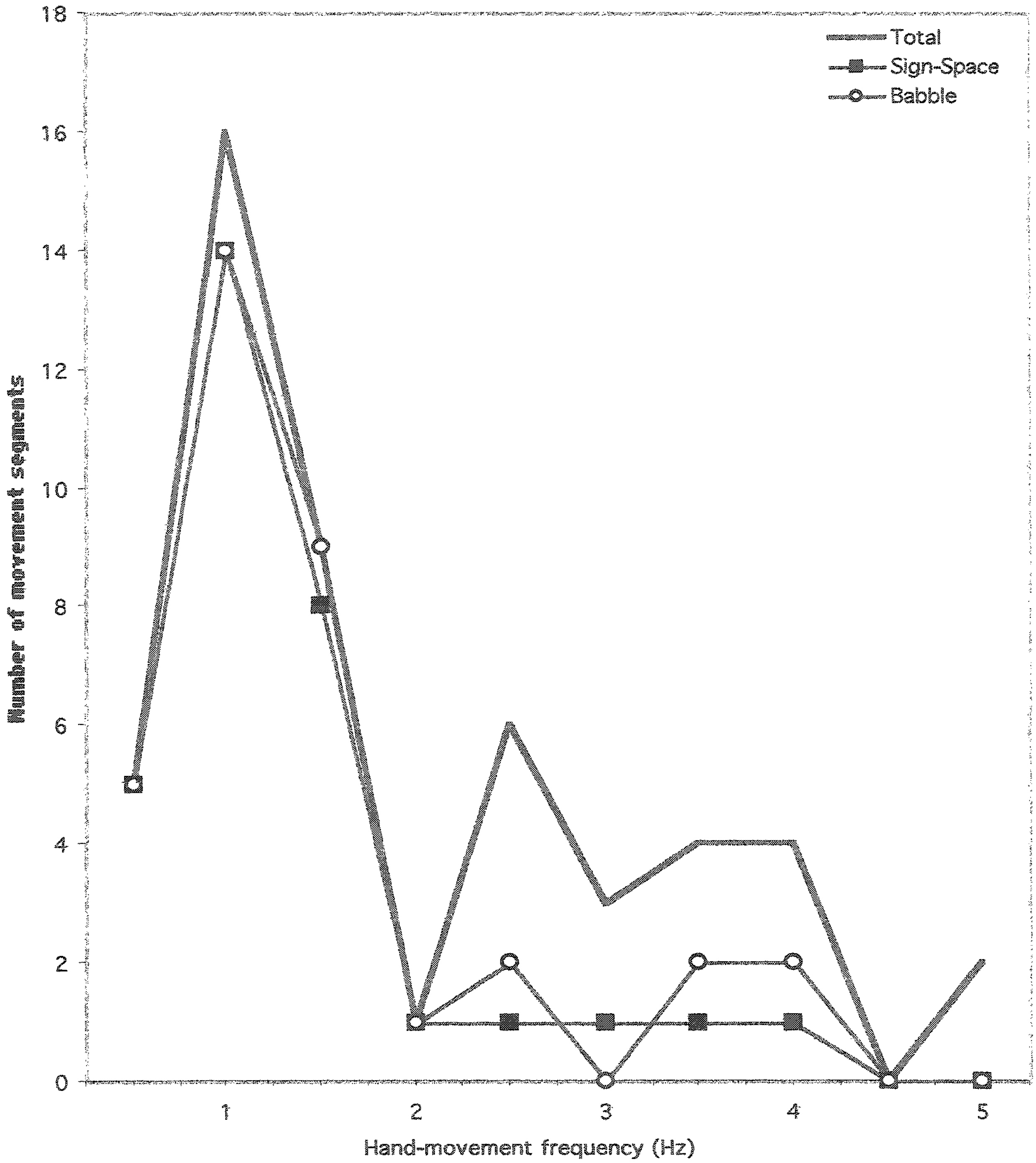

Figure 3

Distribution of the frequencies of sign-exposed baby E2's babbles and sign-space activity relative to the distribution of all movement segments produced.

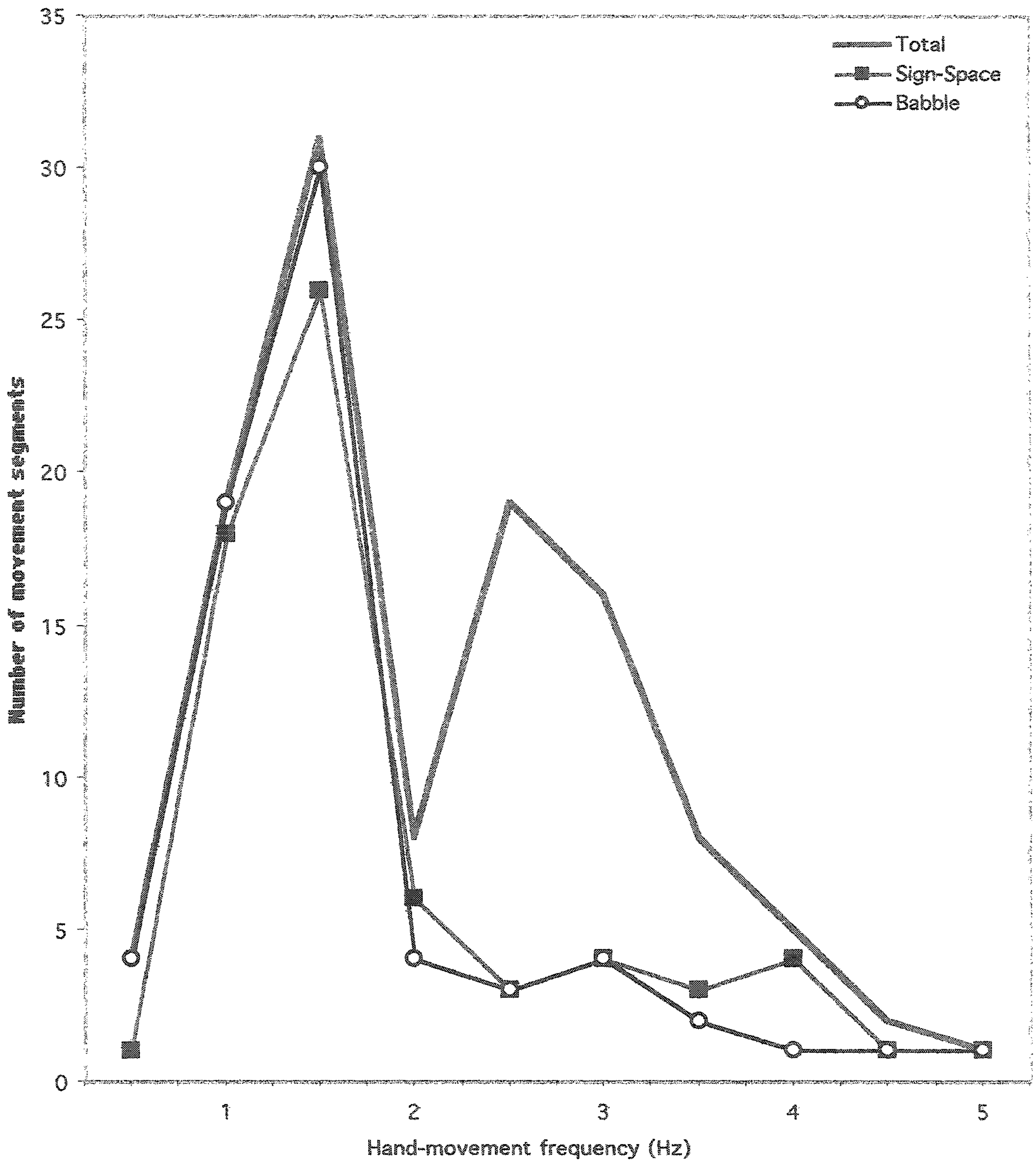

Figure 4

Distribution of the frequencies of sign-exposed baby E3's babbles and sign-space activity relative to the distribution of all movement segments produced.

Chapter 3: Oral Forms

From Manual to Oral Forms

Clues as to the origins of language were provided in Chapter 2 through an investigation of the basis of babbling. From examining the acquisition of language in the manual modality, it was clear that the motoric and linguistic systems could be teased apart. Because only the babies exposed to a signed language produced linguistic manual activity, it was concluded that babies are endowed with a linguistic system distinct from their developing motor systems even before they utter their first words. Moreover, in studying the manual activity of the babies, new properties of manual babbling were posited. First, it was discovered that manual babbles were produced at a frequency distinct from that of all other non-linguistic manual activity. Second, manual babbling, like adult signing, was produced in the linguistic signing space.

As with Chapter 2, the study in Chapter 3 was conducted to advance our understanding of the origins of language through studying the basis of babbling. Because a fundamentally linguistic view of the basis of babbling was supported in considering babbling from the *manual* perspective, it was hypothesized that the same would hold true from the *oral* perspective. Unlike the easily observable external articulators of babies acquiring a signed language, however, the vocal apparatus of babies acquiring a spoken language is largely internal. This fact rendered the Optotrak technology employed in Chapter 2 unsuitable for studying whether a distinction exists between the motoric and linguistic systems of babies' oral forms. A well-established technique was therefore borrowed from the adult literature and applied for the first time to babies' oral activity as a means of shedding new light on the neural underpinnings of babbling. The results enhanced our understanding of the basis of babbling, and hence the origins of language, and contributed to the existing criteria for identifying vocal babbles as distinct from all other oral forms produced by babies.

Manuscript 2

Left Hemisphere Cerebral Specialization for Babies While Babbling

Siobhan Holowka

Laura Ann Petitto

Holowka, S. & Petitto, L.A. (In Press). Left Hemisphere Cerebral Specialization for Babies While Babbling. *Science*.

In press for publication in *Science*.

Abstract

Babies' oral activity was examined for mouth aperture asymmetry. We found that babies' babbles were produced with right asymmetry (reflecting left hemisphere language specialization), equal mouth opening with non-babbles, and left asymmetry while smiling. This first-time demonstration of left hemisphere specialization for babbling sheds new light on language's neural underpinnings.

Acknowledgements

We thank D.W. Holowka, K. Dunbar, U. Harasymowycz, and K. Byers-Heinlein.

L.A.P. was funded by the Social Sciences and Humanities Research Council of Canada, The Spencer Foundation, and Dartmouth College.

Left Hemisphere Cerebral Specialization for Babies While Babbling

Introduction

Baby babbling is the universal developmental milestone before the onset of language production in humans, yet little is known about whether the neural determinants of this behavior are fundamentally linguistic (Petitto, Holowka, Sergio, & Ostry, 2001; Pinker & Bloom, 1992), or reflect only oral-motor developments (MacNeilage & Davis, 2000; Locke, 2000). In adults, the presence of right asymmetry in mouth aperture during linguistic tasks as contrasted with left or equal mouth opening during non-linguistic tasks has been widely used as a key measure of left hemisphere cerebral specialization for language (Graves & Landis, 1990). Given the non-invasive nature of mouth asymmetry studies, this technique is ideally suited to inferring whether functional cerebral asymmetries of babies' earliest productions exist. If babbling is fundamentally linguistic in nature, then left hemispheric specialization should be reflected in right mouth asymmetry while babbling. If babbling is fundamentally motoric in nature, then equal hemispheric participation should be reflected in equal mouth opening while babbling. The results will provide insight into the neural basis of babbling and hence into the origins of human language.

Methods

To control for any language-specific effects of mouth asymmetry, we videotaped 10 babies acquiring either English (n=5) or French (n=5). The babies were studied between the ages of 5 and12 months, according to the age at which each baby first entered the syllabic babbling stage. Once this developmental milestone was achieved, we examined three types of oral activity produced by the babies: babbles, nonbabbles, and smiles (Table 1). Babbles were defined as vocalizations that contained a reduced subset of possible sounds (phonetic units) found in spoken language, had reduplicated (repeated) syllabic organization (consonant-vowel alternations), and were produced without apparent meaning or reference; all vocalizations lacking any of these three criteria were coded as nonbabbles. Spontaneous smiles were coded as an additional control of babies' specificity of mouth opening for distinctive types of oral activity (Graves & Landis, 1990).

At 50 ms (three video frames) from initial lip opening, two "blind" independent coders scored 150 randomly selected segments of babbles, nonbabbles and smiles according to whether greater right, left or equal mouth opening was observed. A standard Laterality Index (LI; Graves & Landis, 1990) was computed for each baby for their production of babbles, nonbabbles and smiles: LI=(R-L/R+L+E), and mean LI scores were calculated for each group of babies (English and French). Thus, a mean positive LI score indicated more instances of right mouth opening, and a mean negative LI score indicated more instances of left mouth opening for the given production.

Results

The mean LI scores clearly indicated that all babies had right mouth asymmetry while babbling, equal mouth opening while nonbabbles were produced, and left mouth asymmetry while smiling (Figure 1). Statistical analysis was performed using a two-way mixed analysis of variance: group (English and French) x production (babble, nonbabble, smile). No significant effect of group was detected ($F=0.09$, n.s.), indicating that no significant differences were found between the English and French babies (Table 1). A significant main effect was discovered for production ($F=236.91$, $p<0.001$), and all pair-wise comparisons were significant ($p<0.001$), indicating that the babies' mouth opening differed depending on whether a babble, nonbabble, or smile was produced.

Discussion

The origins of language in humans have remained elusive as a result of controversy over the neural basis of babbling. Like adults, the right mouth asymmetry observed in babies suggests left hemisphere asymmetry for babbling, reflecting the human left hemisphere control of natural language. If babbling were simply a way for the baby to flex the motor control system for the mouth, tongue, and throat--no different from the system used in chewing--then symmetry in mouth opening would have been observed. Instead, we witnessed an asymmetrical pattern of mouth opening for babbling, which supports the fundamentally linguistic view that babbling reflects babies' sensitivity to and production of patterns in the linguistic input (Petitto et al., 2001). We thus conclude that babbling represents the onset of the productive language capacity in humans, rather than an exclusively oral-motor development.

This discovery demonstrates left hemisphere cerebral specialization for babies while babbling, which in turn, suggests that language functions in humans are lateralized from a very early point in development. Moreover, the smile results illustrate the specificity of the right-sided mouth advantage of babbling behavior in babies, corroborate classic neuropsychological adult studies (Gazzaniga & Smylie, 1983), and suggest that, like adults (Borod, Kent, Koff, Martin, & Alpert, 1988), babies' emotional expression may be controlled by the right hemisphere even at the early age of 5 months. Ongoing research is exploring the feasibility of using this mouth asymmetry technique as a means for detecting potential language deficits in babies even before they utter their first words, which represents the earliest measure of its type to date and sheds light on the emergence and neural foundation of higher human cognition.

References

Borod, J. C., Kent, J., Koff, E., Martin, C., & Alpert, M. (1988). Facial asymmetry while posing positive and negative emotions: Support for the right hemisphere hypothesis. *Neuropsychologia, 26*(5), 759-764.

Gazzaniga, M. S. & Smylie, C. (1983). Facial recognition and brain asymmetries: clues to underlying mechanisms. *Annals of Neurology, 13*(5), 536-540.

Graves, R., & Landis, T. (1990). Asymmetry in mouth opening during different speech tasks. *International Journal of Psychology, 25*(2), 179-189.

Locke, J. L. (2000). Movement patterns in spoken language. *Science, 288*(5465), 449-451.

MacNeilage, P. F., & Davis, B. L. (2000). On the origin of internal structure of word forms. *Science, 288*(5465), 527-531.

Petitto, L. A., Holowka, S., Sergio, L. E., & Ostry, D. (2001). Language rhythms in baby hand movements. *Nature, 413*(6851), 35-36.

Pinker, S., & Bloom, P. (1992). Natural language and natural selection. In J. H. Barkow & L. Cosmides & et al. (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 451-493). New York: Oxford University Press.

Table 1

Individual and Group Data Showing Right, Equal, or Left Mouth Activity in English and French Babies While Producing Babbles, Nonbabbles, and Smiles

Group	Baby	Gender	Age[a]	Laterality Index (LI)[b]		
				Babbles	Nonbabbles	Smiles
	E1	Male	10;00	0.8	0	-1
	E2	Male	05;26	1	0	-1
English	E3	Female	11;10	1	-0.2	-0.4
	E4	Female	12;00	1	-0.2	-0.8
	E5	Female	12;04	0.8	0	-1
		Mean LI (English)		0.92	-0.08	-0.84

(table continues)

Group	Baby	Gender	Age[a]	Laterality Index (LI)[b]		
				Babbles	Nonbabbles	Smiles
	F1	Female	09;27	0.8	-0.2	-0.6
	F2	Female	08;00	0.8	0	-1
French	F3	Female	08;13	1	0	-1
	F4	Male	10;02	0.8	0	-0.6
	F5	Male	09;01	0.8	-0.2	-0.8
		Mean LI (French)		0.84	-0.08	-0.80
		Mean LI (All)		*0.88*	*-0.08*	*-0.82*

Note. 1. Table 1 contains the individual data from the study of mouth opening asymmetry for vocal babbles, nonbabbles, and smiles in two groups of 10 normally developing and normally hearing babies (5 English and 5 French). Because babies were tested according to the age at which they first entered the syllabic babbling stage (vocalizations containing a reduced subset of possible phonetic units, with reduplicated or repeated syllabic consonant-vowel alternations, and produced without apparent meaning or reference) the exact age of each baby at testing and the age of onset of syllabic babbling are one and the same and, thus, appear here under the single heading "Age[a]". A standard Laterality Index (LI)[b] (Graves & Landis, 1990) was computed for each baby according to whether greater Right, Equal, or Left mouth opening was observed when producing babbles, nonbabbles and smiles, with a mean positive LI score indicating more instances of right mouth opening and a mean negative LI score indicating more instances of left mouth opening. The Table shows that both individually, and by group, all babies had right mouth asymmetry while babbling, equal mouth opening with non-babbles, and left mouth asymmetry while smiling.

[a]Age = Months;days

[b]Laterality Index (LI) = (Right-Left/Right+Left+Equal).

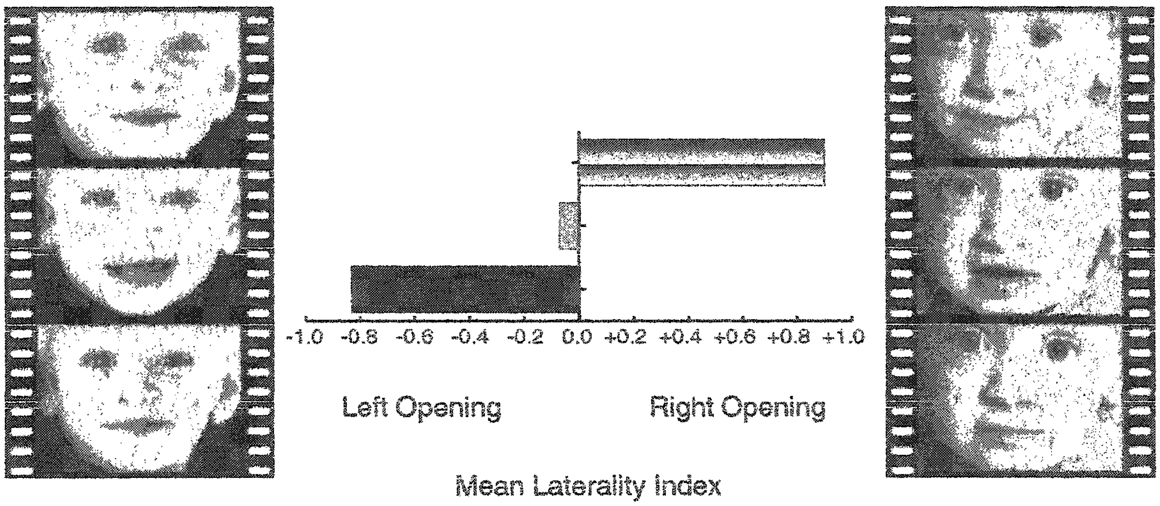

Figure 1

Consecutive frames from video recordings showing a baby's left mouth opening while smiling (left), and right mouth opening while babbling (right). Mean LI scores for all of the babies were as follows: babble = +0.88 (stripes), nonbabble = -0.08 (gray), and smile = -0.82 (black)

Chapter 4: Manual and Oral Forms

From Form to Meaning

The findings from Chapters 2 and 3 suggested that the basis of babbling was fundamentally linguistic in nature, which in turn, suggested that the origins of expressive language reside in the syllabic babbles of babies. These findings held across both the signed and spoken modalities, and new properties defining babbles were demonstrated for each mode. In the manual modality babies' babbles were produced in the canonical linguistic signing space, and were produced at a frequency distinct from other manual activity. From the oral perspective it was determined that like a well-established property of adult language, linguistic activity was under left hemisphere control.

The studies in Chapters 2 and 3 provided new insight into the *origins* and *properties* of emerging language, and thus the study in Chapter 4 was designed to investigate the *processes* underlying early language acquisition. More specifically, how babies make the transition from form (babbles) to meaning (words) were examined, by studying how babies constrain, organize, and use their first words. As Chapters 2 and 3 examined babies from the manual and oral perspectives respectively, these processes were studied in babies acquiring a manual and an oral language *simultaneously* in Chapter 4. By comparing babies acquiring a signed and a spoken language simultaneously to babies acquiring two spoken languages simultaneously, hypotheses regarding the processes underlying *all* language acquisition were tested. Examining the acquisition of two languages in two different modalities had the added advantage of accounting for individual differences across babies, as the manual and oral languages were examined in the same child. Furthermore, it made possible the testing of new hypotheses regarding universal semantic and conceptual underpinnings that transcend modality differences in the same baby. In sum, the results provided new insight into contemporary theoretical and methodological issues in the field of bilingualism, and in turn, into the processes underlying all acquisition.

Manuscript 3

Semantic and conceptual knowledge underlying bilingual babies' first signs and words

Siobhan Holowka

Francoise Brosseau-Lapré

Laura Ann Petitto

Holowka, S., Brosseau-Lapré, F., & Petitto, L.A. (2002). Semantic and Conceptual Knowledge Underlying Bilingual Babies' First Signs and Words. *Language Learning, 52(2)*, 205-262.

Abstract

We addressed the question of how babies exposed to two languages simultaneously acquire the meanings of words across their two languages. In particular, we attempted to shed new light on whether babies know that they are acquiring different lexicons right from the start, or whether early bilingual exposure causes them to be semantically confused. We proposed a collection of research methods that, taken together, can answer these questions, which have hitherto received scant attention. Six hearing babies were videotaped for one hour on average seven times over one year (ages ranging from 0;07 to 2;02); three babies were acquiring French and English, and three French and LSQ. These populations offer unique insights into the semantic knowledge underlying bilingual as well as monolingual language acquisition. We found that the babies (i) acquired their two languages on the same timetable as monolinguals and (ii) produced translation equivalents in their very first lexicons. Further, their early words (signs) in each language (iii) were constrained along kind boundaries, (iv) showed fundamentally similar semantic organization across their dual lexicons, and (v) reflected the meanings of their favorite things first. We also discuss why attributions that young bilinguals are delayed and confused have prevailed and we show that they are neither at this point in development. Finally, the present findings show how research of this type can provide a method for making bilingual norms wholly attainable.

Acknowledgements

We thank the Deaf and hearing parents who gave us their time and allowed us to study their children. We are grateful to Darren W. Holowka and Kevin Dunbar, and to the anonymous reviewers who provided comments on earlier versions of this manuscript. We also thank Ulana Harasymowycz, Kristine Gauna, Ioulia Kovelman, and Gissella Santayana for assistance on details of manuscript preparation. This research was funded by the following grants to L.A. Petitto: Social Sciences and Humanities Research Council of Canada, as well as The Spencer Foundation (U.S.A.). L.A. Petitto also wishes to thank The Guggenheim Foundation.

Semantic and conceptual knowledge underlying bilingual babies' first signs and words

Introduction

Determining the meaning of words is a problem that has perplexed philosophers and scientists for centuries and remains an active topic of debate to this day. Determining how the young monolingual acquires word meanings--especially words for objects--is even more puzzling and has spawned a vibrant sub-discipline of study in child language. Researchers studying babies acquiring two languages from birth have also been faced with the problem of determining how these young bilinguals acquire the meanings of their very first words. But here, unlike studies of monolinguals, our understanding of what young bilinguals know about the meanings of words across their two languages has received surprisingly little scientific scrutiny. In the present paper, we hope to offer three fundamental insights into (i) how bilingual babies acquire early word meanings in each of their two languages over time, (ii) how word meanings are conceptually constrained and semantically organized for each language, and (iii) what research methods might best help us gain this knowledge. To achieve these goals, we focus our attention on a fascinating group of young bilinguals--babies acquiring French and Langue des Signes Québecoise (LSQ)--in addition to babies acquiring French and English, because, together, they offer us an unique lens into the semantic landscape of the young bilingual mind.

How does the monolingual child acquire word meanings?

In his classic observation, the philosopher Quine (1960, 1980) noted that there are numerous possible meanings for any word defined by ostension. If, for example, a mother points towards a rabbit in a room which also contains a cat and a dog, and says "rabbit," how does the child know that (a) she is referring to the rabbit in the room, as opposed to the cat or the dog, and (b) she is referring to the whole rabbit and not a part: for example, its whiskers, color, or ears? These and other problems of word learning have stimulated decades of research that have provided insights into how children acquire word meanings. While we cannot capture the full richness of this literature here, below we provide but a brief sketch of key reasoning and refer the reader to the following for important contemporary discussion of this topic (e.g., Bloom, 2000; Carey, 1982; Golinkoff & Hirsh-Pasek, 1999; Hollich, Hirsh-Pasek, & Golinkoff, in press).

Taylor and Gelman (1989) proposed that perhaps children rely on heuristics and strategies to induce the meanings of early words. One strategy that children may employ to grasp the meanings of new words is by identifying clues from linguistic form class (e.g., Carey, 1982; Taylor & Gelman, 1989). In English, for example, syntactic form class can help children distinguish between common nouns and proper nouns. Katz, Baker, and Macnamara (1974) illustrated this point in their landmark study by presenting 18-month old girls with a doll named "Dax." These girls proceeded to call only this particular doll "Dax" and refrained from calling all other dolls by the name "Dax."

Subsequently, when another group of baby girls was introduced to the same doll as "*a* Dax," the children applied the name "Dax" to all dolls. Thus, the children acquired the meaning of "Dax" by recognizing that the determiner "a" marks common nouns as distinct from proper nouns in English.

Markman (1992) identified another possible strategy used by children to induce the meanings of new words called the mutual exclusivity constraint, which biases children toward acquiring a single label for each object in the world. One advantage of this constraint is that children can acquire new words for objects by inference. Thus, in the example above, according to the mutual exclusivity constraint, if the child knew the labels for *cat* and for *dog*, then she would infer that "rabbit" refers to the other animal in the room for which she did not have a name (the rabbit). While the strategies proposed by Taylor, Gelman, Markman, and others may enable children to acquire the meanings of new words, these strategies assume both a basic vocabulary and a basic knowledge of syntactic structure and, as such, may be problematic for babies acquiring the meaning of their very first words (see also Clark's 1988, "principle of contrast" below).

How can researchers study the bilingual child's word meanings?

Researchers studying babies acquiring two languages simultaneously have also been concerned with how they acquire word meanings and, in particular, researchers have been concerned with the intricacies faced by bilingual babies when acquiring the semantic concepts behind two languages. One possibility, for example, is that bilingual babies "know" that they are acquiring two distinct language systems (i.e., termed the "differentiated language system hypothesis;" c.f. Genesee, 1989; for other proponents see Deuchar & Quay, 2000; Genesee, Nicoladis, & Paradis, 1995; Lanza, 1992; Meisel, 1989; Petitto et al., 2001). Alternatively, young bilinguals may begin by thinking that words from their two different languages constitute a single language system that eventually becomes differentiated over the first few years of life (i.e., termed the "unitary language system hypothesis" by Genesee, 1989, although he has not advanced this view; e.g., see instead, Redlinger & Park, 1980; Vihman, 1985). This latter view implies that young bilinguals may be initially confused in sorting out the semantic concepts underlying early words across their two languages.

In the following section, we will outline a multifaceted approach to evaluate these competing hypotheses, and other issues surrounding the young bilingual's word meanings and their semantic and conceptual underpinnings, by using a combined methodology with several key components: Analyses of the (i) presence of cross-language synonyms, which yields information about what young bilinguals know about the meanings (semantics) of words and their related underlying concepts across their two languages and sheds light on whether young bilinguals differentiate their two languages from the start; (ii) conceptual underpinning of early lexical meanings, which yields information about whether word meanings are conceptually constrained; and (iii) categorization of basic word meanings and concepts, which yields information about the young bilinguals' categorization of semantic concepts across each of its two languages over time, as well as identifies any universal patterns in what topics children select to talk about first. Two other methodological considerations are raised that we believe, if taken together with the above three approaches, can fundamentally advance our understanding of how bilingual babies acquire early word meanings and how word meanings are semantically and conceptually organized in each of their two languages. These considerations include arguments in support of (iv) use of multiple data sources when studying young bilinguals and (v) comparisons of bilinguals to established monolingual norms.

Presence of cross-language synonyms or translation equivalents (TEs). An intriguing and recurring question in the research literature about young bilingual babies' early two lexicons is whether they can possess a word for a specific object like a doll in, for example, French "*poupée*," and, at the same moment in development, also posses the word for this identical object in their other language, for example, English "doll." This is not a matter of whether, like monolinguals, they possess words with overlapping meanings (like "cup" and "glass"), but whether they can have an identical word, like "cup," for an identical referent (a cup) in each of their two lexicons at the same time, especially in their set of first words.

Because in their classic study of bilingual children Volterra and Taeschner (1978) did not observe such "cross-language synonyms," or more recently called "translation equivalents" (TEs), for nearly two decades a prevailing view had been that young bilinguals do not and ostensibly cannot produce them. This was presumably because bilingual babies initially possess a single, fused linguistic system that contains largely semantically undifferentiated words from both languages, with all of the underlying conceptual confusion that this would imply.

Are bilingual babies' early lexicons semantically and conceptually undifferentiated? Are they semantically and conceptually confused? If, as some had claimed, bilingual babies do not possess two lexical items for an identical referent (one from each of their languages), then this could be considered evidence that they are initially semantically and conceptually confused. Following from this very logic, however, we suggest that if young bilinguals do possess two lexical items for an identical referent in each lexicon at the same time, then this would provide evidence that they are not semantically and conceptually confused. We fully appreciate that TEs alone would not constitute the sole evidence needed to establish that young bilinguals have knowledge of one versus two linguistic systems, but it would be an important part of the combined methodology that we offer here in an attempt to gain insight into what young bilinguals know about their two languages from the start. Said another way, the discovery of TEs in the vocabulary of young bilinguals, in combination with the other methods here, would imply that they are not confused by words from each of their languages that refer to the same referent (and to same underlying concept, and mean the same thing) because they "know" that they are acquiring two distinct languages--which is precisely what we and several other recent researchers have argued after having discovered TEs in the vocabularies of young bilingual subjects (e.g., Pearson, Fernandez, & Oller (1995); Petitto et al., 2001; see also Nicoladis, 1998, and Quay, 1995, who report the existence of TEs in a Portuguese-English child, and in a Spanish-English child, respectively). Nicoladis (1998) further proposed that children's understanding of appropriate pragmatic use of their two languages may be linked to their knowledge that their TEs belong to two distinct linguistic systems.

An important clue that bilingual babies may not possess underlying semantic and conceptual confusion when acquiring word meanings across two different languages emerged from a key study by Pearson et al. (1995) that examined the presence or absence of TEs in the vocabularies of young bilinguals. They studied 27 Spanish-English bilingual children, and reported that on average approximately 30% of an individual bilingual child's early vocabulary words was judged to be semantic TEs. Further, to explain the apparent paradox as to why young bilinguals could learn two different lexical forms for the same item in the first place--especially given the literature's proposal of "constraints" to block this from occurring in monolinguals--the researchers considered several possible explanations, one which we find especially ingenious: Specifically, they invoked Eve Clark's (1988) "principle of contrast," which states that monolingual children will reject the acquisition of synonyms due to their bias towards acquiring a single label for each item in the world: The researchers reasoned that this principle must apply within one of a young bilingual's two languages thereby blocking within language synonyms, but not across their two languages, thereby permitting cross-language synonyms or semantically related TEs.

Most recently, TEs have even been discovered to exist "cross-modally," that is, in young bilinguals acquiring both a spoken and a signed language from birth. Based on age and vocabulary achievement, Petitto and her students (2001) matched a bilingual child acquiring French and LSQ and a bilingual child acquiring French and English with two of Pearson and colleagues' (1995) subjects acquiring Spanish and English. They observed that their subjects produced TEs, and at a comparably high rate as those observed in Pearson's study. Specifically, Petitto's French-English child's TEs constituted 50% and 36% of the child's total vocabulary at ages 1;02 and 1;05, respectively; but compare this to the child observed by Pearson and her colleagues whose TEs also constituted 50% and 36% of its total vocabulary at the same ages. Similarly, Petitto's LSQ-French child had TEs that constituted 40% and 51% of their total early vocabularies at the same ages, with another of Pearson's subjects producing 41% and 36% at these two ages. Taken together, these recent cross-linguistic and cross-modal studies of semantically related TEs provide insight into what young bilinguals know about the meanings of words across their two languages and, together with the other methods offered here, suggest that bilinguals know they are acquiring two languages from the start.

Conceptual underpinnings of early lexical meanings. No studies to date have specifically examined the semantic and conceptual underpinnings of a bilingual infant's two lexicons (beyond the TE analyses above) and, thus, we must turn to these particular studies of monolinguals to gain insight into how we might study the semantic and conceptual knowledge that underlies early bilingual acquisition.

In an earlier study, Carey (1982) suggested that the semantic content of the linguistic context directs the child's attention. Carey's proposal implies that by capturing the context surrounding babies' productive vocabulary, and by examining babies' patterns of word use, researchers may infer children's early word meanings (see also Mandler, 1981). Though developed independently, Huttenlocher and Smiley (1987) and Petitto (1988) applied this basic reasoning and developed a common methodology for studying the semantic and conceptual underpinnings of monolingual babies' first words. Using a similar videotape transcription and coding procedure, the researchers inferred the meaning of deaf (Petitto, 1988) and hearing (Huttenlocher & Smiley, 1987; Petitto, 1988) babies' first words (signs) by examining each lexical item and the range of referents over which it was applied, as well as the reverse (examining all referents and each lexical item used with them). Together, these studies provided a method for obtaining insights into the conceptual knowledge underlying babies' very first words by examining both "correct" and "incorrect" pairings of lexical forms and their referents (be they "referents" that are extensional or intensional; the word "context" here refers to every contextual event and/or situation surrounding the babies' production of each sign and/or each word). In the earliest stages of language acquisition babies may overextend the meanings of words across multiple referents and thus "mislabel" common objects. For example, having acquired the label *dog* children may refer to all four-legged animals (including cows, horses, cats, and the like) as *dogs*. Children's tendency to overextend words in this way, has elicited controversial views in the literature (see Bloom, 2000 for an excellent review). Earlier studies, for example, indicated that children rarely overextend their earliest words; Hildegard, a child observed by Leopold (1939-1949), for example, overextended only approximately 20 words out of a total number of over 300 words, while Rescorla's (1980) research indicated that one third of children's early vocabulary may be overextended (see also Clark, 1973; Volterra & Taeschner, 1978).

In a more recent study, Petitto (1992) applied previously established methods (Huttenlocher & Smiley, 1987; Petitto, 1988) to investigate whether overextensions reflected constraints on an emerging conceptual organization. Researchers' earlier assertions suggested that word meanings are constrained along kind boundaries (e.g., kinds of objects, events, locations, possessions, and so forth), and tend not to violate these boundaries (e.g., Clark, 1973; Huttenlocher & Smiley, 1987; Keil, 1989; Leopold, 1939-1949; Rescorla, 1980; Volterra & Taeschner, 1978). Petitto examined monolingual babies acquiring either a signed or a spoken language and found virtually no violations of kind boundaries; only 3/577 tokens constituted possible violations (e.g., the lexical form "open" was used only to refer to the *action* or *event* involved in opening objects, and was not used to *name* the object being opened). Thus, Petitto's study suggests that these constraints hold across both the signed and spoken modalities in monolinguals, but whether this is also true of babies *simultaneously* acquiring a signed and a spoken language remains unknown.

Categorization of basic word meanings and concepts. Babies' first words are thought to be governed by their personal interests, such as their favorite toys, friends, and foods (Dromi, 1987; MacWhinney, 1998; Mervis, 1984; Nelson, 1973; Ninio & Snow, 1988; Slobin, 1985). In her classic study, Nelson (1973) proposed a procedure for categorizing these first words as a means of better understanding babies' underlying conceptual organization. The hierarchical procedure involved organizing monolingual babies' first 50 words into various conceptual domains, as Nelson believed that babies differentiated these conceptual categories from the onset of language production. Irrespective of the limitations inherent in subjectively organizing babies' first words into "semantic trees," Nelson's procedure proves useful in comparing categories of word meanings across infants. Furthermore, Nelson's semantic categorizations of her subjects' productions do reflect similar findings by at least one bilingual researcher, with the classic studies of Leopold (1939-1949) providing the one case in point. Though Leopold developed his system approximately 40 years prior to Nelson's, he created a hierarchical procedure similar to hers in his semantic classification of Hildegard's English and

German vocabularies. Despite the different language(s) being acquired (including, the vastly different time periods, language contexts, and rearing conditions), both Nelson's monolingual subjects and Leopold's bilingual subject demonstrated remarkable similarities in the types of early vocabulary items produced (the things that they talked about across all languages) and, most importantly, in the semantic groupings that cohered them. Thus, this lone study of a bilingual child raised in the 1940s by Leopold suggests a pattern of conceptual organization common to both monolingual and bilingual babies that transcends an impressive array of linguistic and contextual differences between the two groups. Crucially, it compels us to study this issue more closely, as (to the best of our knowledge) no one considered this issue since Leopold.

Use of multiple data sources. Pearson (1998) rightly noted that there are currently no standardized methods for measuring bilingual babies' early linguistic achievements. Earlier case studies, for example, have examined the development of two languages over time using diaries as the primary source of data (e.g., Leopold, 1939-1949; Ronjat, 1913; Taeschner, 1983; Volterra & Taeschner, 1978). The problems of generalizability and reliability associated with relying exclusively on journal or diary entries, however (see Deuchar & Quay, 2000; Dromi, 1987, for further discussion) have more recently prompted researchers to use either (i) videotapes (e.g., Genesee, Boivin, & Nicoladis, 1996), or (ii) parental checklists/reports (e.g., Pearson et al., 1993; 1995), or (iii) a combination of sources (e.g., Deuchar & Quay, 1999, 2000; Petitto et al., 2001; Quay, 1995; Vihman, 1985) to overcome these limitations in their investigations of one or more bilingual children's productions. Pearson (1998) also stated that using multiple sources to obtain data from bilingual babies' early productions is a definite improvement over measures employed in the past because they provide a more representative measure of bilingual babies' achievements, while cautioning that they may not always give the bilingual infant full credit in terms of linguistic knowledge. Sensitive to such caveats, in Petitto and students' study (2001), as well as in the present study, three sources of data collection were used--in addition to a fourth crucial check on the three--to ensure that the data were representative of the bilingual child's linguistic achievements at any given time: extensive videotape recordings made at every experimental session (primary source data of the actual children), use of the MacArthur CDI's (parental checklists/secondary source data), and detailed videotaped interviews conducted with parents and family at every experimental session (parental reports/secondary source data). In addition, detailed experimenter notes were made both during and immediately after a session and used as an important external validity measure of the three data sources above (e.g., to check that at least one of the above three data sources contained a vocabulary item that may have been observed off-camera; as a basis to know whether the child was on the cusp of an important language milestone and consequently to ensure proper scheduling of the next visit; as a means to assess critical developmental, cognitive, and social developmental milestones). What our use of combined methods has taught us is that such methods can and do provide the richest and most comprehensive profile possible of the young bilingual, and are best situated as the foundation upon which bilingual research must rest.

Comparisons of bilinguals and established monolingual norms. The above concerns raised by Pearson (1998) regarding the assessment of bilingual babies' linguistic development are commensurate with earlier caution raised in the bilingual field at large. Grosjean (1989), for example, in his important research with bilingual adults, made the well-known assertion that the bilingual is not two monolinguals in one person. While acknowledging that there are clearly differences and variations in early linguistic development of bilingual babies relative to monolinguals, Nicoladis and Genesee (1997) have nonetheless provided evidence for similarities between the two groups. In terms of linguistic milestones, for example, Nicoladis and Genesee found that no differences exist between the developing monolingual child and the developing bilingual child, providing that both of the bilingual child's two languages are taken into account. Although this issue is far from settled, several recent studies of bilingual babies acquiring a myriad of languages (including signed languages), and including those directly comparing bilingual and monolingual groups, have generally corroborated this new perspective: if we take the young bilingual's two languages into consideration, we will find that, combined, their linguistic milestones are comparable to the well-established monolingual norms (e.g., Nicoladis & Genesee, 1997; Pearson et. al., 1995; Petitto et al., 2001; Quay, 1995), with the classic monolingual milestones being the achievement of the first-word milestone between ages 0;09 and 1;02 (e.g., Capute et al., 1986; Vihman & McCune, 1994), the first two-word combinations between ages 1;05 and 2;02 (e.g., Brown, 1973; Bloom, 1975; Petitto, 1987), and the first 50 words (types) at approximately 1;07 (e.g., Charron & Petitto, 1991; Nelson, 1973; Petitto, 1987). Therefore, direct comparisons of a young bilingual's productions with monolingual norms should continue to be fruitful as long as each of the bilingual child's two languages are evaluated and as long as the focus rests squarely on discerning both the similarities *and* the differences between the two groups.

Objectives

The overarching goal of the present research is to contribute new information regarding the semantic and conceptual knowledge underlying bilingual babies' first words. Specifically, we ask how bilingual babies acquire early word meanings in each of their two languages, and how word meanings are conceptually constrained and semantically organized for each language. It is also our objective to uncover a set of key research methods that together will best help us gain this knowledge. To achieve these goals, we examine bilingual babies, first-hand, prior to the onset of their first words until approximately age two across multiple language contexts, including those in which we varied novel and familiar language users. We examine both bilingual babies acquiring two spoken languages (English and French) simultaneously and bilingual babies exposed to a spoken and a signed language (LSQ and French). The latter signing-speaking group was studied to gain insight into the semantic knowledge underlying all bilingual language acquisition. For the sake of clarity, we first outline our hypotheses and predictions relative to the order that the analyses are presented in the Results section of this paper, followed by a brief discussion of the special questions that the study of young signing-speaking bilinguals permit us to address.

Bilingual language milestones. First we evaluate whether the overall developmental language milestones are the same across the signing-speaking bilinguals as compared to our bilinguals acquiring two spoken languages (and as compared to the literature). In addition to answering when (what age) young bilinguals attain the classic language milestones, this analysis also establishes crucial information about what the basic set of word meanings is for each child across each of their two languages over time. Following from Petitto and her students' (2001) study of a smaller sample of babies acquiring two spoken languages and babies acquiring sign and speech, as well as from the important studies of Nicoladis and Genesse (1997), Pearson and colleagues (1995), and others, we predict the following: All of our bilinguals' achievement of the classic language milestones in *each* of their two input languages should be comparable, and, overall, the ages at which all infants achieve each language milestone should be comparable to those of monolinguals. If confirmed, the results would provide cross-linguistic and cross-modal empirical validity to the field's growing perspective that, developmentally, the bilingual child's two languages, together, are comparable to monolingual language development (e.g., Nicoladis & Genesee, 1997; Pearson et al., 1995; Petitto et al. 2001), as well as providing the essential data over which subsequent semantic analyses can proceed.

Cross-language synonyms. Having established the basic vocabularies and their meanings for each child across each of their two input languages over time, we can analyze the data for the presence or absence of cross-language synonyms or TEs. One goal was to evaluate the important observation from previous findings that TEs are indeed a robust phenomenon constituting approximately one-third of a child's total combined lexicons. Here, however, we conduct our analyses using both (i) the multiple data sources described above, including the use of primary data from our bilingual babies because Pearson and colleagues' (1995) observations were drawn exclusively from secondary sources involving parental checklists, and (ii) a larger sample of babies because Petitto and students (2001) examined TEs in two babies. Another goal is that we sought to gain key insights into the semantic underpinnings of their early lexicons. If TEs are found in our babies' vocabularies, then it would suggest that they are not semantically confused and provide further support for the view that bilingual babies can differentiate their two language systems as early as the first word stage. If, on the other hand, the babies are semantically confused, then this might be evidence by a marked absence of TEs.

Conceptual underpinning of early lexical meanings. To understand the underlying conceptual "glue" that binds early lexical items and their meanings, we compare and contrast the relationship between all lexical items in each language and the range of referents over which they apply (and vice versa), paying special attention to the nature and extent of "overextensions" and/or other semantic "errors" of meaning. The import of this analysis rests both in its first-time application to the dual lexicons of bilinguals and in the insights that follow from it: specifically, this analysis provides a fascinating window into the core conceptual principles that guide early word learning. It especially permits us to test two prevailing hypotheses about the underlying principles that bind words and their meanings in early monolingual language acquisition: early lexical meanings are constrained along "kind boundaries" (e.g., kinds of objects, kinds of events, kinds of locations; or, taxonomically) and/or according to associative lists of meanings (e.g., the word "cookie" means: the object cookie, the container that they are kept in/jar, the location where they are stored/top of refrigerator; or, thematically). Should we find that each of a bilingual child's lexicon is constrained, and constrained similarly, we will gain insights into the underlying conceptual principles that bind the child's lexical knowledge. Additionally, it will suggest testable new hypotheses about possible universal conceptual principles that bind early word learning across all language acquisition.

Categorization of basic word meanings and concepts. Working hand in hand with the above analysis, we ask how word meanings (and corresponding semantic concepts) may be categorized in each of a young bilingual's two lexicons. Specifically, we asked whether bilingual children "talk" about the same types of things as monolinguals, and do they do so in each of their two languages. Dromi (1987), MacWhinney (1998), Mervis (1984), and Slobin (1985) have hypothesized that children first acquire names for things that are of personal interest. Using a procedure similar to that developed by Nelson (1973) for monolingual babies, our goals here are twofold: First, our goal is to establish whether the dual lexicons of young bilinguals exhibit fundamentally similar categorical organization as would be revealed through similar Nelson-type semantic trees. Our second goal is to investigate whether bilingual babies first acquire meanings for things that are related to them, and, if so, to examine whether they do so in each of their two languages. While this possibility has been suggested for babies acquiring a single language from birth, to date no studies have examined this question in bilingual babies. As above, should we find important similarities in the categorization of word meanings across bilinguals (involving each of their lexicons) and monolinguals, we will have gained insight into possible universals regarding the types of things that children will talk about--those that may underlie all early language acquisition.

Special insights from studying young signing-speaking bilinguals

Analyses of signed languages have revealed that, like spoken language, they are lateralized in the left hemisphere (e.g., Bellugi, Poizner, & Klima, 1989) and utilize identical brain tissue as hearing speakers when processing identical linguistic functions (e.g., phonetic-syllabic units in sign are processed in the identical secondary auditory tissue as hearing people; Petitto et al., 2000). Signed languages also exhibit the same levels of language organization (e.g., phonemic, morphological, syntactic, discourse) and are acquired in similar ways as spoken language (e.g., Newport & Meier, 1985; Petitto, 1987, 1992; Petitto & Marentette, 1991). Further, recent developments in bilingual research have suggested that bilingual babies acquiring both a signed and a spoken language do so along the same maturational time course as monolingual babies (e.g., Petitto et al., 2001). We may thus conclude that a child exposed to a spoken and signed language from birth is indeed in a bilingual situation similar to a child exposed to two languages from birth.

At the same time, unlike the baby acquiring two spoken languages, there exists a key dramatic difference: the signing-speaking baby's two languages are produced and perceived in entirely different modalities (manual-visual versus oral-aural, respectively). It is this very difference that can be employed to shed new light on the semantic and conceptual underpinnings of babies' early productions. For example, because some individual signs in signed languages are "iconic" (pictorial, representational; e.g., a cupped hand shape raised to the lips is the formal sign for TASSE or cup in LSQ), and because some other signs are outright "indexical" (e.g., pointing to self is the formal sign for MOI or me in LSQ, and pointing to other is the sign for TOI or you) it could be that this type of bilingual child's sign lexicon may constitute a fundamentally different class of lexical items than in his or her speech. While it has already been well established by Petitto (e.g., 1987) and others, that sign iconicity does not play a major role in monolingual deaf children's acquisition of signs, the key question here is whether we will discover sign and speech lexicons conveying vastly different semantic meanings in these young signing-speaking bilinguals. If there are true universals in underlying semantic and conceptual knowledge, then they should reveal themselves with common semantic relations expressed across sign and speech, thereby overriding modality differences.

In summary, the study of bilingual signing-speaking babies enables us to test specific hypotheses about bilingual acquisition. In particular, we hope to shed new light on whether young bilinguals differentiate their two languages from the onset of language production and further make establishing bilingual norms attainable. Moreover, we asked what bilingual babies know about their two languages and precisely when they know it, including whether their early word meanings are constrained, and how their early concepts are organized. By comparing the bilingual babies acquiring a signed and a spoken language from birth to bilingual babies acquiring two spoken languages, we attempt to answer these questions in order to enhance knowledge of the semantic and conceptual foundation upon which bilingual language acquisition rests.

Methods

Participants

Six hearing babies participated in this study. Three hearing babies were acquiring French and English, and the other three hearing babies were acquiring LSQ. The babies acquiring the two spoken languages served both as a control group with which to compare our experimental group (the babies acquiring a signed and a spoken language), as well as an experimental group with which to compare to other studies of young bilinguals--with all six babies also being compared to the well-documented norms of monolingual language development. All the babies had regular and consistent exposure to both of their input languages from birth, and each parent of each child identified himself or herself as using primarily one language with their child.[i] Nonetheless, all 6 babies had a parent who stayed at home and a parent who worked outside of the home during the day; a situation which predicts variation in the amount of lexical items across the babies' two languages (i.e., we would expect a baby to have more French words if she stayed at home with her French mother during the day; we elaborate more on this topic in the Discussion section of this paper).

The babies were studied over a one year period: Videotaped sessions took place monthly before the production of their first words (first signs) in each of their input languages. Once the "first-word" linguistic milestone was achieved, the babies were subsequently videotaped tri-monthly until approximately two years of age. Note that the babies were studied before the production of their first words and were followed beyond their first 50 words in each of their two languages. The babies were videotaped in a comfortable living room designed for babies and parents at McGill University. Table 1 provides information about the babies.

Procedure

All experimental sessions with the babies and their families were videotaped by a research assistant. The research assistant filmed the babies through a window and did not participate in the sessions. Our sessions were designed to provide interesting and multiple contexts (involving multiple language users), and a setting as natural as possible, during which we could observe a child's dual language productions, over time. In each session parents were instructed to use the language that they "normally" use with the child, when addressing the child, each other, or the experimenters, which in all cases was the adult's native language. Two monolingual experimenters (each a native speaker of one of the babies' native languages) also played with the babies during the sessions (at different times) in order to ensure that an opportunity existed for the child to use each of her languages, and to do so with adults other than immediate family members. Past studies have shown that employing novel monolingual experimenters (who do not understand the child's second language) is a highly effective way of eliciting productions in the experimenter's language, since babies tend to accommodate the interlocutor in order to make themselves understood (e.g., Genesee, Boivin, & Nicoladis, 1996).

In a typical session, first, the child interacted freely with both parents and experimenters. Parental reports of the babies' linguistic development were obtained at this time in the form of an on-line videotaped interview. Then the baby was left alone to play and converse with one parent, and then the other parent was left alone to play and converse with the baby. After this, the baby was left to converse and play with an experimenter who was a native speaker (signer) of one of the baby's languages, and, following this, the baby played with a different experimenter who spoke (signed) the baby's other language. Finally, all experimenters and parents present played together with the baby; each of these situations lasted for approximately 10-15 minutes. Thus, approximately one hour of primary videotape data per baby was captured on videotape for each baby per session. The entire length of the videotaped sessions of all six babies was then fully transcribed, and the babies' verbal and manual productions were attributed lexical status according to the "transcription and coding" procedures outlined by Petitto et al. (2001).

Detailed notes were taken by experimenters of their observations of the babies' linguistic abilities, noting comprehension and production in each language, both during and immediately following each videotaped session. After every session, parents were asked to complete MacArthur Communicative Development Inventories (CDI; Fenson et al., 1991) for babies (designed for ages 0;08 to 1;04), for each of the babies' two languages, noting both the words (or signs) that they produced and comprehended. The French parents were given a CDI that was both translated into and adapted for French (Trudeau, Frank & Poulin-Dubois, 1997). Following Petitto and her students (2001; see also Deuchar & Quay, 1999, 2000; Quay, 1995; Vihman, 1985) the on-line interview with the parents, experimenters' reports, and CDI's were used to ensure that the videotaped samples were representative of the babies' linguistic achievements and were commensurate with published standardized norms. Together, the CDI's and the productions captured on videotape were used to obtain the order of the acquisition of the babies' first word through their first 50 words in both languages, and the ages of the babies at each of the 1-, 10-, 30-, and 50-word milestones.

To gain insight into babies' early word meanings in each of their respective input languages, we coded every word or sign that the babies produced (as established by the criteria for attributing lexical status to infants' forms by Petitto et al., 2001), and the apparent item (referent) that it was used in relation to (extensionally or intensionally), as well as the reverse--for every referent, the entire range of words (signs) used in relation to it using standard CHILDES transcription format (MacWhinney, 1995). Thus, meaning was determined by examining the babies' use of a lexical item in relation to the range of referents over which it was applied (Petitto, 1992). Each lexical item-referent pairing was then coded as being either "appropriate" or "inappropriate." These terms were not intended to "pre-judge" the meaning(s) of the babies' productions, but rather to provide a manner by which the "inappropriate" terms may be identified quickly as distinct from the hundreds of other forms produced by the babies. For example, if an infant produced the word (sign) "ball," and it was used in relation to a ball, it was coded as "appropriate." Whereas, if the word (sign) "ball" was used in relation to a cup, for example, it was coded as "inappropriate." Once each lexical item-referent pair was coded in this manner, all of the "inappropriate" instances were individually scrutinized.

To shed light on how bilingual babies' first word meanings are organized, the babies' first 10, 30 and 50 words were categorized according to the semantic structure classification system used by Nelson (1973; see Figure 1). The procedure used here to classify the bilingual babies' early productions, however, differed from Nelson's procedure in two ways.

First, because Nelson (1973) herself acknowledged that her fourth level of semantic classification varied as a function of individual differences among children, we subdivided each of our bilingual babies' two lexicons into Nelson's first three levels only. Briefly, and as is illustrated in Figure 1, Nelson's semantic categorization system divided the first level *Objects* and *Nonobjects*. The second level further divided Objects into *Animate* and *Inanimate* objects, and the category of Nonobjects was further subdivided into *Person-related* and *Object-related* categories. The third level of classification then split animate objects into *People* and *Animals*, and inanimate objects into *Personal* and *Impersonal*. The Person-related, Nonobjects category was split into *Action* and *Expressive*, and the Object-related words into *Action* and *Properties*. According to Nelson, these first three levels of classification are common to all children. With regard to Nelson's fourth level of classification (not used here), this level varied across children and was dependent upon the child's lexicon and observed use. For example, all but one of

Nelson's subjects, Lisa, had a category of "body parts", which was classified under Personal, Inanimate, Objects (see Nelson, 1973, for further examples of fourth level subdivisions). We did not apply this fourth level of classification to our babies' early words because we were interested in gaining insight into how all children categorize their early concepts (and not into individual differences which the fourth level of classification provides). Thus, we collapsed the fourth level of the semantic trees to gain a better understanding of whether all of the bilingual babies' first 50 words reflected their personal interests.

Second, here we conduct first-time analyses of bilingual babies' first words in *both* languages until the 10-, 30- and 50-word milestones were achieved, yet Nelson (1973) studied only monolinguals.

Lexical items were arranged according to the semantic structure specified by Nelson (1973) for each baby (according to the template seen in Figure 1) at three different times: Time 1 (T1) = first 10 words, Time 2 (T2) = first 30 words, and Time 3 (T3) = first 50 words. Following the literature, we included the babies' words from each language at each time (Pearson et al., 1993; Nicoladis & Genesse, 1997); for example, a baby might have three French words and seven English words at the 10-word milestone. Although we held T1, T2, and T3 constant across each child, these times often occurred at different ages for different babies. Ed, for example, reached the 10-word milestone

(T1) at 14 months, while Oli was only 12 months at T1. As a result, the intervals between T1, T2, and T3 also vary by infant.

Reliability

The videotapes of all experimental sessions were fully transcribed twice; each time by a native user of each respective language heard or seen on the videotape; for example, an LSQ deaf signer transcribed each tape for the child's signed utterances and then a French speaker transcribed the tapes for the French utterances. Two additional transcribers (one for each language) performed reliability checks on lexical attributions, with respect to both the lexical gloss (type) and its tokens in addition to other coding judgements. Agreement amongst coders was initially 83% (regarding both agreement that a linguistic event had occurred and agreement concerning what occurred within the linguistic event or its' linguistic content and classification of its' content, including lexical attributions). Through discussion, all disagreement regarding both coding and lexical attributions was resolved and yielded 100% agreement.

Results

Analysis I: Early Linguistic Development: The Classic Milestones & Lexical Growth

The age of attainment of the bilingual babies' first words were determined at (a) the first-word milestone in each language, (b) the first 50-word milestone in each of the babies' languages, and (c) the age at which 50 words were attained using words from both languages (e.g., the time at which the infant has, for example, 20 English words and 30 French words). This analysis was performed to compare the babies' linguistic development across groups and to the well-established monolingual norms. The results are presented in Table 2; all six bilingual babies achieved the classic milestones in each of their native languages at approximately the same time. The babies acquiring French and English attained their first word between 0;11 and 1;02 years in each of their languages. Ed, an English-French infant, produced his first words in both languages at the same time; Jane produced a word in English first, followed approximately two months later with her first French word; Sue produced her first word in French and then her first English word approximately one month later. The English-French babies produced their first 50 words between the ages of 1;04 and 2;02 in at least one of their languages. While only Sue produced 50 different words in each language, all babies acquiring the two spoken languages produced 50 different words using both languages between the ages of 1;04 and 1;11.

The LSQ-French babies produced all of their first words in both languages at the same time and all at 11 months of age. All 3 babies had 50 words in French between 1;08 and 1;11. Only Oli had 50 words in both French and LSQ at 2;01, but all 3 babies had 50 words using both languages between 1;07 and 1;08.

The average age of attainment of the English-French and of the LSQ-French babies' first word and first 50 words (in both languages combined) are given in Table 3, and are compared to monolingual norms. While the LSQ-French babies attained both linguistic milestones on average slightly earlier than the English-French babies, all of the bilingual babies' ages at the time of their early productions were commensurate with monolingual norms.

The number of types of words or signs produced by each young bilingual over time was also examined relative to monolinguals (see Figure 2). The "neutral" forms appearing in Figure 2 are lexical forms that could not be judged as being either French or English because of their immature phonology (e.g., a baby's production "ba" could refer to either the French adult form "balle" or the English form "ball"). A few proper names used in both languages were also included in the class of neutrals (e.g. Mickey, Big Bird) for the English-French babies, whereas modality differences in the LSQ-French babies made it clear which language was being used from their very first attempts at language production (signed versus spoken).[2]

The general trend for all of the babies was an increase in vocabulary types in each of their two languages over time. Only one LSQ-French subject, Val, did not follow that trend; she produced fewer words in her last session as compared to previous ones. Upon closer examination, however, the decline in vocabulary types in each of her two languages is proportional; she did not suddenly cease producing words in one language while productions in her other language flourished. For all of the babies studied here, the rate and growth of vocabulary types in one language is more rapid than in the other, but the development of the two languages parallel each other (i.e., productions in both languages either increased, or in the case of Val, decreased proportionately over time). Taken together, these results indicated that all of the bilingual babies attained the classic linguistic milestones, and demonstrated lexical growth in each of their two languages along the same maturational time course as monolingual babies (e.g., Capute et al., 1986; Vihman & McCune, 1994).

Analysis II: The Nature of Early Word Meanings: Do Young Bilinguals Produce Translation Equivalents?

Following Pearson and her colleagues (1995) and Petitto and her students (2001), the percentages of TEs present in the six babies' first 50 words were derived by counting the total number of TEs present in the babies' vocabularies and dividing it by 50. The results yielded similar percentages of TEs across the English-French babies, 25%, 28%, and 28%, and across the LSQ-French babies, 20%, 26%, and 42%. The average percentage of TEs present in the babies' total 50-word lexicons were thus remarkably similar at 27% and 29% for the English-French and LSQ-French groups respectively. These averages were also similar to those reported for the bilingual babies in the Pearson and Petitto studies, and suggests that bilingual babies do possess two words (one from each language) that can refer to the identical referent that are used appropriately without apparent semantic or conceptual confusion and lends support to the hypothesis that they "know" that they are acquiring two languages.

Analysis III: The Nature of Early Word Meanings: Are Bilingual Babies' Early Word Meanings Constrained?

All forms produced by the babies that were deemed lexical from the criteria for lexical attributions established by Petitto and her students (2001), were further coded as to the range of referents in relation to which the lexical form was used (and vice versa). Each lexical item and referent pairing was then coded as being either appropriate or inappropriate. This analysis provided insight into whether the relationship between a child's lexical form and its apparent referent (be it intensional or extensional) was principled, and whether it was bound along "kind boundaries," both within one of his or her native languages and across his or her two native languages, over time. "Kind boundaries" included, for example, kinds of objects, events, locations, and possessions (e.g., Clark, 1973; Huttenlocher & Smiley, 1987; Keil, 1989; Leopold, 1939-1949; Petitto, 1992; Rescorla, 1980; Volterra & Taeschner, 1978). For example, if the word *cup* was used for an object that can contain liquid, that we can lift to our lips, and from which we can drink, it was coded as "appropriate." If the word *cup* was used in relation to a plate, it was coded as "inappropriate;" these terms were not intended to pre-judge the child but were used only as a heuristic in our computer database that enabled us to analyze many utterances and to quickly find such non-standard (or "inappropriate") pairings for subsequent scrutiny. Referent-linguistic form pairings that were not used along particular boundaries were counted as "violations" of kind boundaries (again, used here as a heuristic to be able to find them, should they exist, in large corpora for subsequent scrutiny).

The findings regarding this analysis are presented in Table 4. Over the course of our examination of the babies, only 3.5% (259/7381) inappropriate tokens were observed or an average of 43 tokens per child (each individual infant produced between 15 and 70 inappropriate tokens). Of the 148 inappropriate tokens produced by the French-English bilinguals, only six did not respect kind boundaries. Similarly, of the 111 inappropriate tokens produced by LSQ-French bilinguals, only nine did not respect kind boundaries. Each of the inappropriate productions was examined individually and the list of examples are provided in Table 5.[3] The most common type of inappropriate productions was overextended forms. Ed, for example, routinely overextended names of animals (i.e., he referred to a horse as *cow*, and to a rabbit as *duck*). Jane, on the other hand, often overextended names of fruits (i.e., she referred to both apples and cucumbers as *bananas*). The patterns of overextensions were similar for the LSQ-French babies as well; Amy overextended names of fruit (i.e., she used the French form *pomme* (apple) to refer to an orange), and Val labeled a horse by producing the French form *chien* (dog). The patterns of overextensions were observed across all babies, occurred in both of the babies' two languages, and accounted for 94% (244/259) of the inappropriate tokens produced by all babies. The inappropriate forms produced by the babies that did violate kind boundaries were exceedingly rare (approximately 6% of all inappropriate forms) and did not exhibit any pattern or regularity (e.g., Amy referred to a banana as *bébé* (baby), and Oli referred to an apple as *nez* (nose). Moreover, these kind violations were relatively evenly distributed through the babies' sessions: The English-French babies' six kind violations occurred at ages 14 (one violation), 16 (four violations), and 19 (one violation) months, and the LSQ-French babies' nine kind violations occurred at ages 12 (three violations), 14 (two violations), and 19 (four violations) months, respectively. Taken together, the results of this analysis suggest that babies do overextend their early forms, but these extensions are constrained within kind boundaries, and these constraints hold across both languages and modalities in the young bilingual over time.

Analysis IV: The Nature of Early Word Meanings: How Are Bilingual Babies' Early Word Meanings Organized?

Following Nelson (1973), three levels of semantic structure were arranged hierarchically to provide insight into how babies' early concepts are organized. Specifically, we were interested in determining whether babies' first words reflect things that are of interest to them. In Nelson's study, a semantic tree was constructed following a template (Figure 1), with the babies' first 10 words (Time 1 = T1), first 30 words (Time 2 = T2), and first 50 words (Time 3 = T3). Similarly, we constructed a semantic tree for one English-French child, Ed (Figure 3), but unlike Nelson's monolingual subjects, Ed's semantic tree included words from both of his two languages including "neutral" forms (i.e., forms that could not be judged as being either English or French, including proper names). The first 10, 30 and 50 words were included here irrespective of grammatical category (i.e., we did not restrict our analyses in any way; nouns, verbs, adjectives, etc., were reported if they were in fact the babies' first words). The data from Ed's tree have been reproduced in the Appendix together with the data from the other two English-French babies, Jane and Sue, with the LSQ-French babies' data, Amy, Val, and Oli, and with three of Nelson's (1973) monolingual subjects, Ellen, Lisa and Robert. The table in the Appendix preserves the semantic structure specified by Nelson, and is thus comparable to the semantic trees used by Nelson in her earlier study.

The semantic structure both within and across the English-French, LSQ-French, and monolingual groups were compared at T1, T2, and T3 by comparing the percentage of words produced in each category. The percentage of words in each category of the table (see Appendix) was calculated by taking the number of words in the category and dividing it by the total number of words at that time. So, for example, if a child had 2 words categorized under "animate objects" at T1 (i.e., 10 words total) then animate objects would constitute 20% (2/10) of the babies' total vocabulary at the 10-word stage. Percentages were taken as opposed to raw numbers because Nelson's subjects did not always have the same number of words at the various times (e.g., Lisa only had 9 words at the 10-word stage).

The first two levels of Nelson's (1973) semantic structure were compared within and across babies at all three times. The results of the analysis at T1 indicated that all three groups of babies produced a large percentage of animate words as their first words, ranging from a total of 20-63% (see Table 6). Only one infant, Sue did not produce any inanimate object words, whereas all the other babies produced a moderate percentage (ranging from 10-22%). All of the babies produced a large percentage of person-related words, ranging from 25-70%. Only two babies, the English-French speaking infant, Sue, and Nelson's monolingual subject, Lisa, produced object-related words at the 10-word stage.

At the 30-word stage (T2), the percentage of animate object words decreased from T1 for all but one LSQ-French subject, Amy (Range: 19-35%; see Table 6). The percentage of inanimate object words increased slightly or remained the same for all of the babies (Range: 10-38%). The percentage of person-related words produced differed by infant at T2. Four babies (one English-French infant, one LSQ-French infant, and two monolingual babies) increased their production of person-related words at T2. In contrast, 1 English-French, 2 LSQ-French, and 1 monolingual infant(s) decreased their production of person-related words, and one infant, Ed, had no change in the percentage of person-related words at T2. The percentage of object-related words increased across all subjects but one, Lisa, at the 30-word stage.

At T3 (the 50-word stage), the percentage of animate object words that the babies produced remained relatively stable from T2 (Range: 16-36%; see Table 6). The percentage of inanimate object words increased for all but one subject, Robert, while the percentage of person-related words decreased for all but one infant, Val. Finally, the percentage of object-related words remained relatively stable for all of the subjects at T3.

In summary, all of the babies' productions at the first two levels of Nelson's semantic structure could be categorized in a similar manner with few exceptions, and followed similar trends across time. In general, the percentages of animate words decreased between T1 and T2 as more words in different categories were being acquired. At T3, however, the number of animate words produced by the babies remained relatively stable from T2, and accounted for approximately one-quarter of all words that the babies produced--compare the average percentage of animate words produced over time: T1 = 44%, T2 = 27%, T3 = 25%. In contrast, the average number of inanimate object words produced by all babies increased steadily: T1 = 15%, T2 = 23%, T3 = 32%. The average percentage of person-related words decreased slightly across time: T1=38%, T2 = 36%, and T3 = 30%, and the average percentage of object-related words fluctuated slightly over time: T1 = 3%, T2 = 14%, T3 = 12%.

To gain further insight into the nature of babies' first word meanings, we then analyzed the babies' productions at the third, more specific, level of classification. To test our hypothesis that babies' early words reflect their personal interests, the classifications of words within the "Object" and "Non-object" categories of the semantic structure were divided into two categories: "person-related" and "non person-related." The "person-related" category encompassed all words which were classified as inanimate, personal (object) words (e.g., doll, milk), and as person-related (non-object) words (e.g., yes, hello). The "non person-related" category included inanimate, impersonal (object) words (e.g., car, telephone), and object-related (non-object) words (e.g., cold, good).

The findings from this analysis revealed that all of the babies produced more person-related than non person-related words at all three times (see Table 7). At T1, an average of 52% of all of the babies' productions were person-related, as compared to a mere 5% average of non-person-related words. At T2, the average percentage of non-person-related words increased to 21%, but the average percentage of person-related words remained virtually the same at 51%. At T3, the average percentage of person-related words increased slightly to 55%, while the average percentage of non person-related words decreased slightly to 20%.

Discussion

The semantic and conceptual knowledge underlying bilingual babies' very first words has been largely unknown. Here we asked how do bilingual babies acquire early word meanings in each of their two languages over time, how are early word meanings conceptually constrained and semantically organized for each language over time, and we further explored research methods that might best help us gain this knowledge. To answer these questions, we studied a fascinating group of bilinguals--young babies acquiring French and LSQ--and we compared them to bilingual babies acquiring French and

English; we further compared all of the bilingual babies to established monolingual norms. The signing-speaking babies' lexical productions in two vastly different modalities enabled us to offer new insights into the knowledge underlying early bilingualism in a manner not possible through the study of two spoken languages alone. Thus, our goal in studying the early semantic and conceptual underpinnings of bilingual babies was to shed new light on this hitherto mysterious aspect of simultaneous acquisition and understand the processes that underlie all early human language acquisition.

The general conclusion to emerge from our first analysis (Analysis I) regarding the age at which young bilinguals achieve the classic early language milestones in each of their two languages was that they exhibited normal language milestones. Overall, each of their two languages was acquired on a similar timetable to the other, and this timetable was similar to young monolinguals. To be sure, none of our young bilinguals demonstrated any protracted or atypical linguistic development relative to monolingual babies.

Regarding specifically the first-word milestone, the English-French babies as well as the LSQ-French babies acquired their first word *in each of their two native languages*, regardless of whether their lexicons were evaluated *separately or combined*, between the ages of 11 and 14 months, which falls within the precise maturational age range observed in monolinguals, or 9 to 14 months (Capute et al., 1986; Vihman & McCune, 1994). For example, while a given infant might achieve her first word milestone in one language at age 11 months and her first word milestone in her other language at 13 months, the key observation is that the infant achieved this classic first-word milestone in each language within the established maturational range for this milestone in all infants (ages 9 to 14 months), which, as will be made clear below, is the most accurate and best index of normal bilingual development.

Regarding the first 50-word milestone, here, on average, all of our babies attained the first 50-word milestone if we considered both of their languages *combined* at around age 1;08, which is similar to the monolingual norm offered for the 50-word milestone of around 1;07 (although surprisingly to our knowledge no age range is provided; Charron & Petitto, 1991; Nelson, 1973; Petitto, 1987). If we considered their two languages separately, our young bilinguals' first 50-word milestone was attained between 1;04 and 2;02, but for reasons that we will discuss in a moment, this is not an accurate index of the maturational time course by which bilingual babies attain the 50-word milestone. Interestingly, separate consideration of their two lexicons vis-à-vis this and other milestones provides one source of the public's perception that young bilinguals are delayed. If, for example, we only examine one language of a given bilingual's two languages at age 1;07 and find that she has only 10 English words, we would indeed have cause for concern. Because what must also be considered is that this child has 40 words in French and, thus, combined, she attained the milestone at the same time as monolingual babies attained the 50-word milestone.

We are justified in considering the young bilingual's combined linguistic achievements, especially as dual language acquisition proceeds over time, for the following reasons. First, we most certainly expected to see variation in the number of vocabulary items that a given infant might produce in one versus the other language of the type that was observed here whereupon, for example, some babies achieved the 50-word milestone first in one of their languages, and then thereafter in their other language. Such variation was expected because it is well known that differences between vocabularies are especially susceptible to environmental factors such as direct vocabulary instruction, drilling, and frequency of exposure, which can yield increases in the amount (number) of vocabulary items that an individual child produces in one language versus the other. At the same time, however, such environmental input factors cannot significantly change the biologically-controlled *maturational age* range within which a normally developing child will achieve a particular language milestone (e.g., Gleitman, 1981; Gleitman & Newport, 1995; Goldin-Meadow, 1981; Petitto et al., 2001). For example, a young baby who is at home all day with her French mother (and who sees her English-speaking dad only at night and on weekends), will indeed end up in early life with more French vocabulary words than English.

Another factor that interacts with amount of environmental input is a child's tendency to produce one versus the other language--and one that can influence children's vocabulary count in either of their two languages--is the young bilingual's own emerging language preference (see Petitto et al., 2001, for a detailed discussion of this). In this study we observed that each child's most frequently used language (the preferred or dominant language) corresponded to the language of its primary sociolinguistic group. This is a fluid construct that could change over time, and whose constitution could change from child to child. In practice, however, a child's sociolinguistic group was the language of the person or group with which the child had both the strongest bond and the most constant contact (e.g., Meisel, 1989). For the children studied here, this was the language of their mother with whom they stayed home all day, but for other children this may be the language of their siblings and friends with whom they were in contact all day. For others still, this may be the primary language of the children and teachers at their full-time day care center. Crucially, we could predict the bilingual child's differential use of their two languages based on our knowledge of their sociolinguistic environment (Petitto et al., 2001).

Finally, there is a growing consensus that the bilingual child may be compared to the monolingual child in terms of development, provided both languages are taken into account (e.g., Nicoladis & Genesee, 1997, Pearson et al., 1995; Petitto et al., 2001). By doing so we see quite remarkably and contrary to earlier views (e.g., Grosjean, 1989), that the rate and pace of bilingual babies' development coincide with the well-established monolingual norms.

In summary, Analysis I revealed that the overall timetable by which young bilinguals' two languages develop is similar to each other, and similar to monolinguals. Crucially, we conclude that it is the maturational timing with which young bilinguals achieve the classic early language milestones (regarding each of their two languages separately and combined) that is the best yardstick by which we should evaluate whether bilingual acquisition is developing "normally" in young children, as opposed to the amount of vocabulary and/or the degree of language use in social contexts that one versus the other language exhibits.

In Analysis II, we examined bilingual babies' two emerging languages, paying attention to words in their dual lexicons with identical meanings (TEs). This provided new insight into the impact that acquiring two languages has on the nascent semantic and conceptual underpinnings of early language. Babies acquiring two languages simultaneously must solve the problem of discerning the semantic meanings and related concepts of two lexicons across their two languages. One strategy that bilingual babies may use is to reject the acquisition of TEs in their early lexicons; by initially rejecting TEs the young bilingual could avoid possible semantic confusion by having a single label for each underlying concept. And in studying young bilinguals, researchers have indeed used the ostensible absence of TEs in babies' vocabularies as an indicator that young bilinguals have an underlying semantic confusion regarding their two languages and do not differentiate between them until around age three (e.g., Redlinger & Park, 1980; Vihman, 1985). Alternatively, the presence of TEs in babies' lexicons has provided researchers with suggestive evidence that young bilinguals can differentiate between their two linguistic systems and as early as their first lexical productions (see especially, Petitto et al. 2001). Following established procedures (e.g., Pearson et al., 1995; Petitto et al., 2001), we calculated the percentages of TEs in all of our babies' vocabularies at the 50-word stage. Like Pearson and Petitto, we found that approximately one-third of the words (signs) in our babies' lexicons contained TEs, thereby corroborating earlier findings but, here, for the first time, we used multiple sources for data collection (cf. Pearson et al., 1995), and a larger sample of babies (cf. Petitto et al., 2001). Taken together, our findings support the hypothesis that bilingual babies do produce TEs and suggests that they do this because they know they are acquiring two distinct lexicons, which is true from their earliest lexical productions and suggests that early bilingual language exposure does not cause a child to be semantically and conceptually confused.

By building upon research methods used to study whether early word meanings in monolingual babies are constrained in any way (i.e., Huttenlocher & Smiley, 1987; Petitto, 1988, 1992), the bilingual babies in Analysis III provided new knowledge into the types of constraints that may underlie their first words in each of their two languages, over time. Examining the lexical-referent pairings of the bilingual babies enabled us to gain an appreciation of the "mistakes" that babies initially make (or as used within "inappropriate" lexical-referent pairings). First, like monolingual babies, we discovered that our bilingual babies rarely overextended their first words in either of their two languages (cf. Clark, 1973; Leopold, 1939-1949; Rescorla, 1980; Volterra & Taeschner, 1978). Moreover, this fact was true for both of their languages from their very first language productions and continued throughout development; lexical use did not become more adult-like (more constrained) as the children grew older, as each of the young bilingual's early lexicons were constrained from their first entry into language production. In addition, for those rare cases when a lexical-referent pairing was judged to be "inappropriate," such pairings were highly patterned: For all six babies combined, a mere 3.5% of the total productions were judged to be "inappropriate," or 259 inappropriate tokens out of a total of 7,381 produced. Of these 259 tokens, only approximately 6% (15 tokens) could be construed as being possible violations of kind boundaries. Thus, with few exceptions, a word used to connote an object was used only to stand for that object and/or the class of related objects, and was not also used to connote other associative or thematic properties of the said object (such as actions, locations, or possessors associated with the object). The present bilingual findings, coupled with evidence from similar findings (see Clark, 1973; Huttenlocher & Smiley, 1987; Keil, 1989; Leopold, 1939-1949; Petitto, 1988, 1992; Rescorla, 1980; Volterra & Taeschner, 1978), lead to the conclusion that early semantic and, thus, conceptual knowledge underlying all language acquisition is highly constrained along kind boundaries, and together they point to the existence of universal conceptual principles that bind early word learning across all language.

By categorizing the babies' words (signs) *in each of their languages* within the hierarchical arrangement suggested by Nelson (1973) at three different time intervals, in our fourth analysis (Analysis IV) we established for the first time that bilingual babies' dual lexicons exhibited overall similar conceptual organization to one another and, crucially, together were highly similar to monolingual babies. We further established for the first time that bilingual and monolingual babies talk about very similar things in early life, with both findings suggesting the existence of universals underlying the ways in which children categorize their early word meanings. Specifically, like monolingual babies, we found that bilingual babies' first 50 words could be organized into four conceptual domains: Objects (animate and inanimate) and Non-objects (person-related and object-related). While the number of words in each category differed by babies, this was also true of the monolingual babies studied by Nelson. Moreover, all of the bilingual babies examined here produced approximately the same number of words (signs) in each of these conceptual domains as monolingual babies. At the 10-word stage, for example, animate words and person-related words together constituted between 80 and 90% of all of the bilingual babies' first words, and between 78 and 88% of the monolingual babies' first words. With few exceptions, the same general patterns across all babies held true at later stages in development as well; at the 30-word stage the percentage of inanimate words increased as did the number of object-related words for all but one infant, and at the 50-word stage the percentage of inanimate objects increased, while the percentage of person-related words decreased for all but one baby. As the babies' vocabularies increased over time, they next acquired the meanings for words in the two other conceptual domains, namely the categories of inanimate objects and object-related non-objects. Given the similarities observed across both monolingual and bilingual subjects collectively, the new insight to emerge from the present findings is that babies first categorize their worlds into animate objects and person-related non-objects.

To gain further insight into the nature of the bilingual babies' first words we tested an hypothesis put forth regarding monolingual babies--we evaluated whether babies acquire the meanings of words for their favorite things first (Dromi, 1987; MacWhinney, 1998; Mervis, 1984; Slobin, 1985). To do this we analyzed the third level of classification in the semantic structure, as Nelson (1973) stated that the first three levels of classification are common to all children. Further, we combined the two conceptual domains, inanimate, personal objects and person-related, non-objects, and created a new category termed "person-related" because these categories contained words that were of personal interest to the babies. We compared this newly formed category to "non-person-related" words, which contained items from Nelson's categories, inanimate, impersonal objects, and object-related, non-objects. These new categories permitted us to determine whether babies first acquire meanings for things that are related to them, and whether this changes over time. In this regard, the novel finding to emerge from the present study is that no significant differences were observed between groups of babies at any time, thereby indicating that all babies, irrespective of whether they were acquiring one or two languages, and irrespective of whether the two languages were spoken or signed, appeared to show a preference for words connoting things that are person-related. This is especially true if one considers that from the very onset of language acquisition (production) approximately half of the babies' words (signs) were person-related. While words describing non person-related items increased over time, the words that were person-related remained prevalent through to the 50-word stage. Together, we conclude that, like monolinguals, bilingual babies' preference for their favorite things is reflected in their early lexical productions and, further, these first meanings are highly organized within the same conceptual domains as monolingual babies.

In the present study we witnessed ways in which signing-speaking babies' language acquisition was similar to bilingual babies acquiring two spoken languages. Together, we saw how these two bilingual groups also provided a cross-linguistic, cross-modal lens through which to observe universals in the knowledge underlying all language acquisition. Despite such similarities, there exist significant differences between bilingual babies acquiring a signed and a spoken language and bilingual babies acquiring two spoken languages.

Babies acquiring two spoken languages do so within a single modality (speech), whereas language acquisition in signing-speaking babies spans two distinct modalities (sign and speech). It was hypothesized that the significant modality differences between signed and spoken languages could yield significant differences between the semantic content of these two languages. Fundamentally different lexicons with vastly different semantic content and organization may have been revealed because signed languages have some lexical items that are made with highly pictorial hand gestures (iconic) and some lexical items that directly pick out relations in front of the signer's body (indexical). Spoken languages, instead, have lexical items whereby their sound sequences are arbitrary in that they are not physically related to the object that they connote. Although it has already been shown that iconic and indexical properties of the lexicon in signed languages do not have an impact on monolingual acquisition of signed languages in profoundly deaf babies (e.g., Petitto, 1987), it could have been the case that such differences in the surface lexical forms of signs versus words yielded fundamental differences in the semantic content of signing-speaking babies' dual lexicons. Instead, what we observed here were striking similarities in the semantic content, underlying conceptual constraints, and semantic organization across these babies' signs and words, over time. This finding provides support for the existence of semantic and conceptual universals underlying all language acquisition (be it monolingual or bilingual)--universals that can even override such significant modality differences.

In summary, the results presented here show that babies exposed to two languages acquire the early linguistic milestones on the same maturational timetable across each language, and on the same timetable as monolingual babies. The bilingual babies produced translation equivalents in their very first lexicons. Their early words (signs) in each language were also constrained along kind boundaries. Further, the categorization of bilingual babies' dual lexicons demonstrated fundamentally similar semantic organization, and were organized similar to those of monolingual babies; our data revealed that our bilingual babies communicated about the same general things across each language, which was similar to monolinguals, and they further acquired the meanings of words (signs) for their favorite things first (those that are person-related). Here we further suggested what might be the root of attributions that young bilinguals are delayed and confused and, crucially, we showed that they are neither and that they differentiate their two lexicons from their first lexical productions. We also presented a collection of research methods that, taken together, can be used to study the semantic and conceptual knowledge underlying both monolingual babies as well as bilingual children's dual lexicons over time--those that can provide data upon which meaningful comparisons between monolingual and bilingual children can be made. Given the unique insights that the bilingual babies acquiring a signed and a spoken language provided us, and given the universal ways in which our bilingual babies acquired their languages relative to monolingual babies, we hope to have provided a means by which future research may make establishing bilingual norms wholly attainable.

Footnotes

1. The bilingual French-English parents did know and speak these two languages, even though each parent claimed to speak only one language with their child (specifically, the language that was his or her own native language from birth). Interestingly, the parents who were deaf and using LSQ were also "bilingual" in LSQ and French in that they did know (have competence in, as distinct from performance) both languages (i.e., the deaf parents did read and write in French). Here, however, they only "spoke" one of these languages with native fluency, that is, LSQ. (Some could produce very few high frequency lexical items in spoken French, such as "Bonjour" meaning hello, although note that their pronunciations differed significantly from standard French); and, of course, they could *not* hear French as the deaf adults in this study were profoundly deaf from birth and acquired LSQ as their first language from their deaf parents or deaf family members. So as to not bias or encourage any infant-directed behavior modification, all of the parents were simply told that this was a study designed to observe their babies' early language acquisition over time.

2. A "neutral" form is a coding attribution designating forms produced by babies that are indistinguishable to researchers as belonging to one or another language. Neutrals have also been suggested to be the cause of babies appearing to be language "confused."

For a discussion of why this is so, and how signing-speaking babies can shed light on this issue, see Petitto et al. (2001), and Petitto and Holowka (2002).

3. For ease of interpretation, the examples given here and in Table 5 reflect the adult forms of the babies' productions.

References

Bellugi, U., Poizner, H., & Klima, E. S. (1989). Language, modality and the brain. *Trends in Neurosciences, 12* (10), 380-388.

Bloom, L. (1975). Structure and variation in child language. *Monographs of the Society for Research in Child Development, 38* (1-2, Serial No. 149): 136.

Bloom, P. (2000). *How children learn the meanings of words*. Cambridge, MA: MIT Press.

Brown, R. (1973). *A first language: The early stages*. Cambridge, MA: Harvard University Press.

Capute, A. J., Palmer, F. B., Shapiro, B. K., Wachtel, R. C., Schmidt, S., & Ross, A. (1986). Clinical linguistic and auditory milestone scale: Prediction of cognition in infancy. *Developmental Medicine & Child Neurology, 28*, 762-771.

Carey, S. (1982). Semantic development: The state of the art. In E. Wanner & L. R. Gleitman (Eds.), *Language acquisition: The state of the art* (pp. 347-389). New York: Cambridge University Press.

Charron, F., & Petitto, L. A. (1991). Les premiers signes acquis par des enfants sourds en Langue des Signes Québecoise (LSQ): Comparaison avec les premiers mots. *Revues Québecoise de Linguistique Théorique et Appliquée, 10* (1), 71-122.

Clark, E. V. (1973). What's in a word? On the child's acquisition of semantics in his first language. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language*. New York: Academic Press.

Clark, E. V. (1988). The principle of contrast: A constraint on language acquisition. In B. MacWhinney (Ed.), *Mechanisms of language acquisition*. Mahwah, NJ: Lawrence Erlbaum & Associates.

Deuchar, M., & Quay, S. (1999). Language choice in the earliest utterances: A case study with methodological implications. *Journal of Child Language, 26* (2), 461-475.

Deuchar, M., & Quay, S. (2000). *Bilingual acquisition: Theoretical implications of a case study*. Oxford: Oxford University Press.

Dromi, E. (1987). Early lexical development. In M. Barrett (Ed.), *The Development of Language*. London: UCL.

Fenson, L., Dale, P. S., Reznick, J. S., Thal, D., Bates, E., Hartung, J. P., Pethick, S. & Reilly, J. S. (1991). *Technical Manual for the MacArthur Communicative Development Inventories*. San Diego, CA: San Diego State University.

Genesee, F. (1989). Early bilingual development: One language or two? *Journal of Child Language, 16*, 161-179.

Genesee, F., Boivin, I., & Nicoladis, E. (1996). Talking with strangers: A study of bilingual children's communicative competence. *Applied Psycholinguistics, 14* (4), 427-442.

Genesee, F., Nicoladis, E., & Paradis, J. (1995). Language differentiation in early bilingual development. *Journal of Child Language, 22,* 611-631.

Gleitman, L. R. (1981). Maturational determinants of language growth. *Cognition, 10* (1-sup-3), 103-114.

Gleitman, L. R., & Newport, E. L. (1995). The invention of language by children: Environmental and biological influences on the acquisition of language. In L. R. Gleitman & M. Liberman (Eds.), *Language: An invitation to cognitive science* (2nd ed., Vol. 1). Cambridge, MA: MIT Press.

Goldin-Meadow, S. (1981). Fragile and resilient properties of language learning. In E. Wanner & L.R. Gleitman (Eds.), *Language acquisition: State of the art.* Cambridge, England: Cambridge University Press.

Golinkoff, R. M., & Hirsh-Pasek, K. (1999). Word learning: Icon, index, or symbol? In R. M. Golinkoff, K. Hirsh-Pasek, N. Akhtar & L. Bloom (Eds.) *Becoming a word learner: A debate on lexical acquisition.* Oxford, England: Oxford University Press.

Grosjean, F. (1989). Neurolinguists, beware! The bilingual is not two monolinguals in one person. *Brain and Language, 36* (1), 3-15.

Hollich, G. J., Hirsh-Pasek, K., & Golinkoff, R. M., (in press). Breaking the language barrier: An emergentist coalition model for the origins of word learning. *Society for Research in Child Development Monographs.*

Huttenlocher, J., & Smiley, P. (1987). Early word meanings: The case of object names. *Cognitive Psychology, 19*, 63-89.

Katz, N., Baker, E., & Macnamara, J. (1974). What's in a name? A study of how children learn common and proper names. *Child Development, 45*(2), 469-473.

Keil, F. C. (1989). *Concepts, kinds, and cognitive development*. Cambridge, MA: MIT Press.

Lanza, E. (1992). Can bilingual 2-year-olds code-switch? *Journal of Child Language, 19*, 633-658.

Leopold, W. F. (1939-1949). *Speech development of a bilingual child: A linguist's record* (Vols. 1-4). Evanston, IL: Northwestern University Press.

MacWhinney, B. (1995). *The CHILDES project: Tools for analyzing talk* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum & Associates.

MacWhinney, B. (1998). Models of the emergence of language. *Annual Review of Pscychology, 49*, 199-227.

Mandler, J. M. (1981). Representation. In J. H. Flavell & E. M. Markman (Eds.), *Cognitive Development* (Vol. 2), of P. Mussen (Ed.), *Manual of Child Psychology*. New York: Wiley.

Markman, E. M. (1992). Constraints on word learning: Speculations about their nature, origins, and domain specificity. In M. Gunnar & M. Maratsos (Eds.), *Modularity and constraints in language and cognition: The Minnesota Symposia on Child Psychology, 25*(1), (pp. 55-99). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Meisel, J. M. (1989). Early differentiation of languages in bilingual children. In K. Hyltenstam & L. Obler (Eds.), *Bilingualism across the life span: In health and in pathology* (pp. 13-40). Cambridge: Cambridge University Press.

Mervis, C. (1984). Early lexical development: The contributions of mother and child. In C. Sophian (Ed.), *Origins of Cognitive Skills* (pp.339-370). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Nelson, K. (1973). Structure and strategy in learning to talk. *Monographs of the Society for Research in Child Development, 40*(2, mono): 1-97.

Newport, E., & Meier, R. (1985). The acquisition of American Sign Language. In D. Slobin (Ed.), *The Crosslinguistic Study of Language Acquisition,* (Vol. 1, pp. 881-938). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Nicoladis, E. (1998). First clues to the existence of two input languages: Pragmatic and lexical differentiation in a bilingual child. *Bilingualism: Language and Cognition, 1*(2), 105-116.

Nicoladis, E., & Genesee, F. (1997). Language development in preschool bilingual children. *Journal of Speech Language Pathology and Audiology, 21*(4), 258-270.

Ninio, A., & Snow, C. (1988). Language acquisition through language use: The functional sources of children's early utterances. In Y. Levy, I. Schlesinger, & M. Braine (Eds.), *Categories and processes in language acquisition* (pp. 11-30). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Pearson, B. Z. (1998). Assessing lexical development in bilingual babies and toddlers. *International Journal of Bilingualism, 2*(3), 347-372.

Pearson, B. Z., Fernandez, S., & Oller, D. K. (1993). Lexical development in bilingual infants and toddlers: Comparison to monolingual norms. *Language Learning, 43*(1), 93-120.

Pearson, B. Z., Fernandez, S., & Oller, D. K. (1995). Cross-language synonyms in the lexicons of bilingual babies: One language or two? *Journal of Child Language, 22*(2), 345-368.

Petitto, L. A. (1987). On the autonomy of language and gesture: Evidence from the acquisition of personal pronouns in American Sign Language. *Cognition, 27*(1), 1-52.

Petitto, L. A. (1988). "Language" in the pre-linguistic child. In F. Kessel (Ed.), *Development of language and language researchers: Essays in honor of Roger Brown* (pp. 187-221). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Petitto, L. A. (1992). Modularity and constraints in early lexical acquisition: Evidence from children's first words/signs and gestures. In M. Gunnar & M. Maratsos (Eds.), *Modularity and constraints in language and cognition: The Minnesota Symposia on Child Psychology*, Vol. 25(1) (pp. 25-58). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Petitto, L. A., & Holowka, S. (2002). Does early simultaneous bilingual language exposure cause children to be language delayed and confused: Special insights from bilingual babies and young children acquiring a signed and a spoken language. *Sign Language Studies*, 33(1).

Petitto, L. A., Katerelos, M., Levi, B., Gauna, K. Tetrault, K., & Ferraro, V. (2001). Bilingual signed and spoken language acquisition from birth: Implications for the mechanisms underlying early bilingual language acquisition. *Journal of Child Language, 28*, 453-496.

Petitto, L. A., & Marentette, P. (1991). Babbling in the manual mode: Evidence for the ontogeny of language. *Science, 25*, 1483-1496.

Petitto, L. A., Zatorre, R. J., Gauna, K., Nikelski, E. J., Dostie, D., Evans, A. C. (2000). Speech-like cerebral activity in profoundly deaf people processing signed languages: Implications for the neural basis of human language. *Proceedings of the National Academy of Science, 97* (25), 13961-13966.

Quay, S. (1995). The bilingual lexicon: Implications for studies of language choice. *Journal of Child Language, 22*(2), 369-387.

Quine, W.V.O. (1960). *Word and object*. Cambridge, MA: MIT Press.

Quine, W.V.O. (1980). Meaning and translation. In H. Morick (Ed.), *Challenges to Empiricism*. Indianapolis, IN: Hackett Publishing Company, Inc.

Redlinger, W. E., & Park, T. Z. (1980). Language mixing in young bilinguals. *Journal of Child Language, 7*(2), 337-352.

Rescorla, L. (1980). Overextension in early language development. *Journal of Child Language, 7*, 321-335.

Ronjat, J. (1913). *Le développement du langage observé chez un enfant bilingue*. Paris: Champion.

Slobin, D. (1985). Crosslinguistic evidence for the language-making capacity. In D. Slobin (Ed.), *The crosslinguistic study of language acquisition: Theoretical Issues*, Vol. 2(1) (pp. 1157-1256). Hillsdale, NJ: Lawrence Erlbaum & Associates.

Taeschner, T. (1983). *The sun is feminine: A study on language acquisition in bilingual children*. New York: Springer-Verlag.

Taylor, M., & Gelman, S. A. (1989). Incorporating new words into the lexicon: Preliminary evidence for language hierarchies in two-year-old children. *Child Development, 59*, 411-419.

Trudeau, N., Frank, I., & Poulin-Dubois, D. (1997). *Inventaire MacArthur du Développement de la Communication: Mots et Gestes* (available from Diane Poulin-Dubois, Concordia University, PY-170, 7141 Sherbrooke St. W., Montreal, QC, Canada H4B 1R6).

Vihman, M. M. (1985). Language differentiation by the bilingual infant. *Journal of Child Language, 12*(2), 297-324.

Vihman, M., & McCune, L. (1994). When is a word a word? *Journal of Child Language, 21*(3), 517-542.

Volterra, V., & Taeschner, T. (1978). The acquisition and development of language by bilingual children. *Journal of Child Language, 5*, 311-326.

Table 1

Ages of Subjects at Videotaped Sessions

English-French		LSQ-French	
Ed	1;00.16	Amy	0;11.30
	1;01.16		1;01.03
	1;02.20		1;02.15
	1;04.01		1;05.13
	1;05.11		1;08.06
	1;07.00		1;11.02
	1;10.20		
	2;01.04		
Jane	0;07.23	Val	0;11.19
	0;10.06		1;00.12
	0;11.10		1;02.10
	1;00.13		1;05.17
	1;01.07		1;08.23
	1;02.08		1;11.04
	1;04.30		
	1;08.08		
	1;11.06		
Sue	1;00.14	Oli	0;11.20
	1;01.15		1;03.14
	1;02.11		1;07.00
	1;03.18		1;10.00
	1;04.22		2;01.06
	1;07.29		
	1;11.02		
	2;02.14		

Table 2

Ages of Subjects at Attainment of the First-Word and First 50-Word Linguistic Milestones

	Milestone				
	First-Word		First 50-Word		
Child	English	French	English	French	English+French
Ed	1;02.20	1;02.20	---------	2;01.04	1;10.20
Jane	0;11.10	1;01.07	1;04.30	---------	1;04.30
Sue	1;02.11	1;01.15	2;02.14	2;02.14	1;11.02
	LSQ	French	LSQ	French	LSQ+French
Amy	0;11.30	0;11.30	---------	1;11.02	1;08.06
Val	0;11.19	0;11.19	---------	1;08.23	1;08.23
Oli	0;11.20	0;11.20	2;01.06	1;10.00	1;07.00

Table 3

Average Age (or Range of Age) of Subjects at Attainment of the First-Word and the First 50-Word Linguistic Milestones

	Milestone	
Group	First-Word	First 50-Word
English-French	1;01	1;09
LSQ-French	0;11	1;08
Monolingual[a]	0;09-1;02	1;07

Note. [a]The monolingual norms for the linguistic milestones were determined from:

(a) First-word: Capute et al., 1986; Vihman and McCune, 1994, and

(b) First 50-words: Nelson, 1973; Petitto, 1987; Charron and Petitto, 1991.

Table 4

Numbers of Appropriate and Inappropriate Tokens

Group	Tokens			
	Total	Appropriate	Inappropriate	Violations
English-French				
Ed	952	937	15	1
Jane	2113	2043	70	4
Sue	923	860	63	1
LSQ-French				
Amy	1344	1304	40	5
Val	706	689	17	0
Oli	1343	1289	54	4

Table 5

Examples of Inappropriate Tokens

	Tokens		
Group	Form	Referent	Kind
English-French			
Ed	*vache* (cow)	horse	animals
	duck	rabbit	animals
	bye	necklace	*
Jane	banana/e[a]	apple	fruits
	banana/e[a]	cucumber	fruits
	mouton (sheep)	cow	animals
	water	photo	*
Sue	woof	cat	animals
	shoe	sock	clothes
	ball	apple	*
LSQ-French			
Amy	CHAT (cat)	dog	animals
	pomme (apple)	orange	fruits
	bébé (baby)	bananas	*

(*table continues*)

	Tokens		
Group	Form	Referent	Kind
LSQ-French			
Val	*chien* (dog)	horse	animals
	OISEAU (bird)	butterfly	animals
	BROSSE-DENT (toothbrush)	hairbrush	brushes
Oli	*auto* (car)	tractor	vehicles
	POMME (apple)	banana	fruits
	nez (nose	apple	*

Note. 1. French forms are in italics, LSQ forms are in capital letters, and English glosses are provided in brackets.

2. The asterix refers to the inappropriate tokens that violated kind boundaries.

[a]Due to her immature phonology, it was unclear as to whether Jane was producing the English form *banana* or the French form *banane*.

Table 6

Percentages of Words Produced by All Subjects at the 10-, 30-, and 50-Word Stage as Categorized by the Nelson Semantic Trees

	Objects						Non-objects					
	Animate			Inanimate			Person-related			Object-related		
Word Stage	10	30	50	10	30	50	10	30	50	10	30	50
English-French												
Ed	50	27	26	20	23	30	30	30	24	0	20	20
Jane	30	23	28	20	20	28	50	47	36	0	10	8
Sue	50	27	24	0	10	24	30	40	30	20	23	22
LSQ-French												
Amy	20	27	26	10	20	28	70	43	36	0	10	10
Val	40	27	22	20	27	28	40	23	32	0	23	18
Oli	50	33	36	20	20	34	30	37	24	0	10	6
Monolingual[a]												
Ellen	45	35	23	22	38	59	33	17	12	0	10	6
Lisa	45	19	16	11	27	37	33	46	37	11	8	10
Robert	63	27	27	12	23	21	25	42	41	0	8	11

Note. [a]Monolingual subject data from Nelson (1973).

Table 7

Percentages of "Person-Related" and "Non Person-Related" Words Produced by all Subjects at the 10-Word (T1), 30-Word (T2), and 50-Word (T3) Stages

	Time					
	T1		T2		T3	
Group	Person-Related	Non-Person-Related	Person-Related	Non-Person-Related	Person-Related	Non-Person-Related
English-French						
Ed	50	0	47	26	50	24
Jane	60	10	64	13	60	12
Sue	30	20	43	30	46	30
LSQ-French						
Amy	80	0	60	13	62	12
Val	60	0	43	30	54	24
Oli	50	0	54	13	48	16
Monolingual[a]						
Ellen	55	0	41	24	57	20
Lisa	44	11	61	20	65	19
Robert	37	0	50	23	51	22

Note. [a]Monolingual subject data from Nelson (1973).

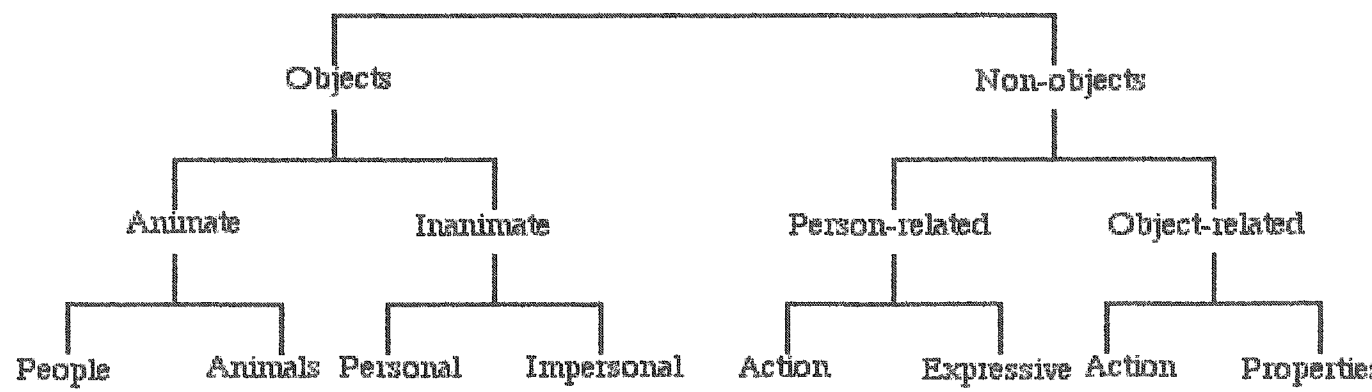

Figure 1

Nelson's (1973) semantic structure: Template

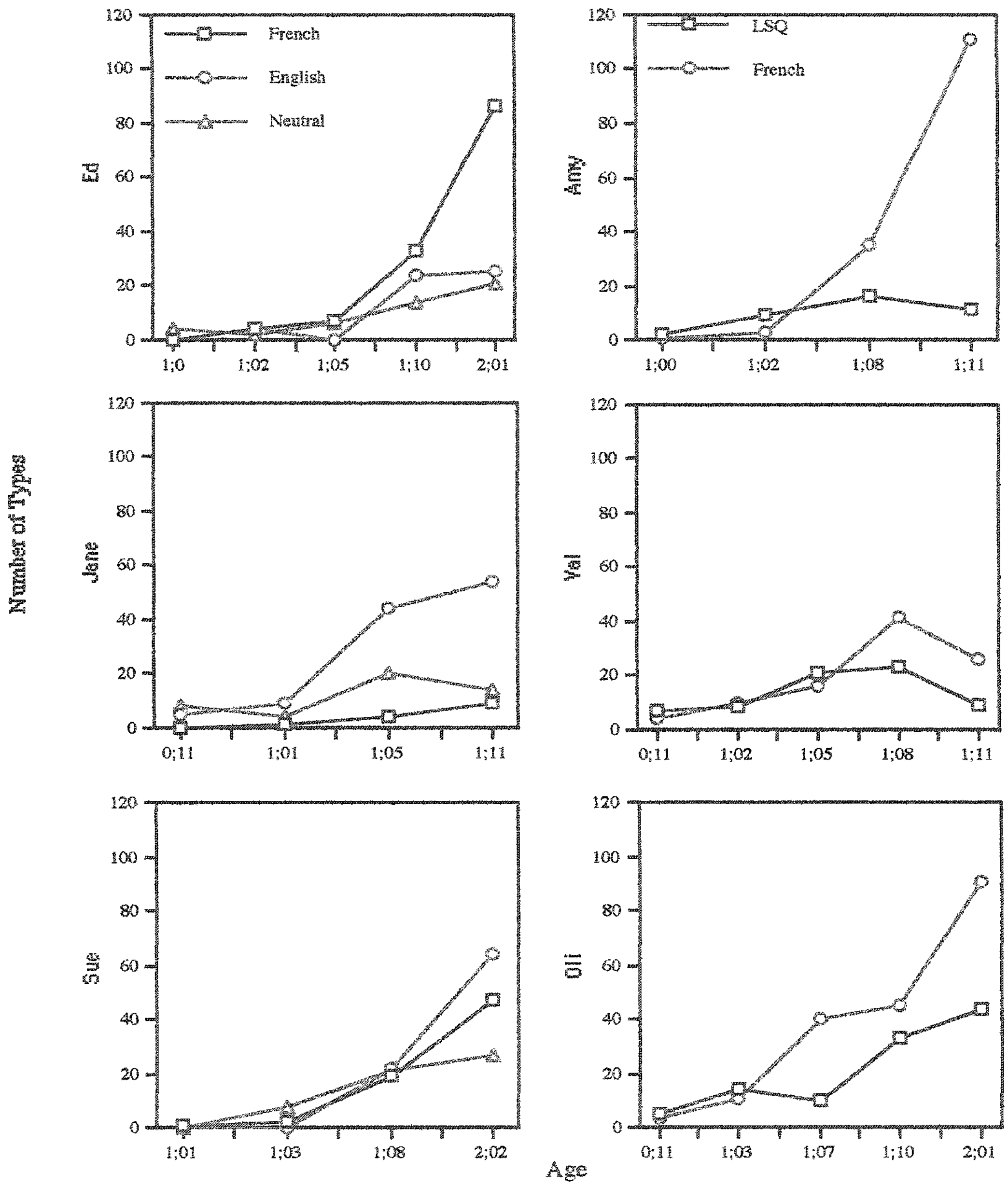

Figure 2

Types of words or signs produced in sessions over time: English-French and LSQ-French infants

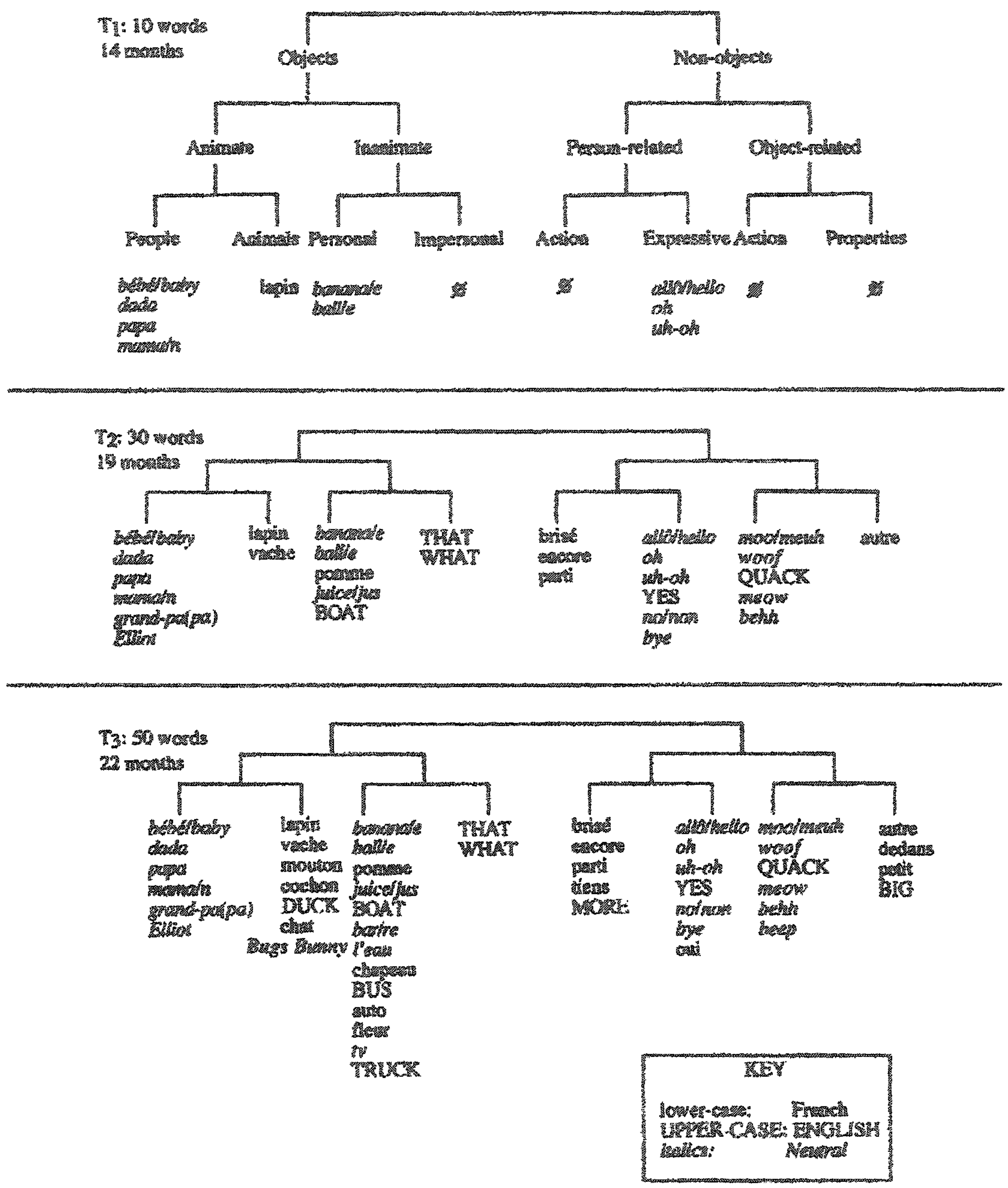

Figure 3

Nelson's (1973) semantic structure for one English-French child: Ed

Appendix

Appendix

Three English-French, Three LSQ-French, and Three Monolingual[a] Subjects' Words[b] Produced at the 10-Word (T1), 30-Word (T2), and 50-Word (T3) Stages According to Nelson's (1973) Semantic Structure

	Objects				Nonobjects			
	Animate		Inanimate		Person-Related		Object-Related	
Group	People	Animals[c]	Personal	Impersonal	Action	Expressive	Action	Properties
English-French								
Ed	*bébé/* *baby* *dada* *papa* *mama/n*	lapin	*banana/e* *ball/e*	∅	∅	*allô/* *hello* *oh* *uh-oh*	∅	∅
T1 = 10								
	grand- *pa(pa)* *Elliot*	vache	pomme *juice/* *jus* BOAT	THAT WHAT	brisé encore parti	YES *no/non* *bye*	*moo/* *meuh* *woof* QUACK *meow* *behh*	autre
T2 = 30								

(appendix continues)

T3 = 50		mouton cochon DUCK chat Bugs Bunny	*bar/re* *l'eau* chapeau BUS auto fleur *tv* TRUCK		tiens MORE	oui	*beep*	dedans petit BIG
Jane T1 = 10	*mama* *baby/bébé*	∅	*banana/e* TOMATO	THAT	AGAIN	HI BYE YES NO	∅	∅
T2 = 30	*dada* *mommy* *maman* *mom* *papa* bébé	BIRDIE	BOOK lait		DOWN UP tiens	non YEAH OKAY oui *bravo*	*beep*	MORE MINE
T3 = 50	*grandpa* YOU *Mitchie* ME I *daddy* *Erik* *Joshie*	*Big Bird*	APPLE JUICE WATER HAT nez	IT	SEE	WANT *ow* *yay* DON'T		

(appendix continues)

	Objects				Nonobjects			
	Animate		Inanimate		Person-Related		Object-Related	
Group	People	Animals	Personal	Impersonal	Action	Expressive	Action	Properties
Sue	*maman*	*Bugs Bunny*	∅	∅	∅	*allô*	*meuh/*	∅
	papa					*hello/*	*moo*	
	mama					*allô*	*woof*	
T1 = 10	*Sarah*					*oh*		
		Puffy	T-SHIRT		regarde	BYE-BYE	*cheep*	
		Jack	BALL		encore	HELLO	*boum-boum*	
		ANIMAL	BANANA			WOW		
		ELEPHANT	JUICE			YEAH		
						ah		
						no/n		
						oui		
T2 = 30						*moi/mine*		
	bébé	PIG	SHOE	THAT	WORK	NO		IN
			SHOES	THIS	DRAW			THERE
			WATER	c'est	ça pique			IS
			balle					A
			banane					
			eau					
T3 = 50			jus					

(appendix continues)

LSQ-French								
Amy T1 = 10	maman BÉBÉ	Ø	LAIT	Ø	ENLÈVE OUVRE DODO dodo	BYE HÉ NON	Ø	Ø
T2 = 30	moi bébé	CHAT CHIEN ours chat	AUTO auto CHAPEAU chapeau	ça	ENCORE bobo	non OH NON OH oh		N'Y A - PLUS DEDANS bon
T3 = 50	papa TOI MAMAN	cochon ourson	chan-dail suce COLLIER SUCE BAIN de - l'eau jus pomme		MANGE tombé	veux OUI oui		là-bas OÙ
Val T1 = 10	MAMAN mama papa bébé	Ø	BALLE suce	Ø	Ø	ALLÔ BYE-BYE OUI HÉ	Ø	Ø

(appendix continues)

Group	Objects				Nonobjects			
	Animate		Inanimate		Person-Related		Object-Related	
	People	Animals	Personal	Impersonal	Action	Expressive	Action	Properties
T2 = 30	PAPA BÉBÉ	CANARD CHIEN	EAU de l'eau CHAPEAU BROSSE-DENT	fleur TÉLÉPHONE		bye-bye BRAVO non	meow	FERMÉ fermé BELLE DEUX BON là
T3 = 50	MOI	OISEAU chien	LAIT POMME banane lait pomme	lumière	MANGE regarde ENCORE PARTI parti tombé	allô CHUT oui	boum	belle
Oli T1 = 10	PAPA MAMAN papa maman	Pitou	LAIT balle	∅	∅	OUI NON BRAVO	∅	∅
T2 = 30	GARÇON	CHIEN DAUPHIN OISEAU singe	lait NEZ nez	TÉLÉPHONE	MANGER MANGE manger mange	allô non oui veux	DODO	DU (LAIT) du (lait)

(appendix continues)

	BÉBÉ	SINGE	POMME	clés		oh		
	bébé	chien	pomme	fleur				
	garçon	oiseau	ballon	téléphone				
		chat	BALLE	FLEUR				
		CHAT	BALLON					
			CHAPEAU					
T3 = 50			chapeau					
Monolingual[a]								
Ellen	DADDY	DOGGIE	DOLLY	∅	GO-GO	HI	∅	∅
	MOMMY		MILK			HI-THERE		
T1 = 10	NANA							
	JUDY	MONKEY	BALL	BUS		HELLO	HOT	ALL-GONE
	CHIPPER	KITTY-CAT	EYES	CAR		NITE NITE		ALL-DONE
	BABY	TURTLE	CRACKERS	SNOW				
			TOAST	THAT				
			SHOES					
T2 = 30								
	ALVIN		BIKE	TRUCK		PLEASE		
			BLOCK	BOAT				
			BREAD	CLOCK				
			BUTTER					
			CHEESE					
			FOOD					
			EGG					
			SPAGHETTI					

(appendix continues)

	Objects				Nonobjects			
	Animate		Inanimate		Person-Related		Object-Related	
Group	People	Animals	Personal	Impersonal	Action	Expressive	Action	Properties
			TRAY SPOON PAPER- (CUP) NOSE EAR LEG SKIN					
T3 = 50								
Lisa T1 = 10	DADDY MOMMY	DAISY PUPPY	BALL	Ø	SEE	HI YES	Ø	WHERE
		DOG	DOLL FORK WATER	CAR KEYS THAT	OUT-SIDE GO EAT DRINK TICKLE	PLEASE THANK- YOU NOT NOW WANT	WOOF- WOOF	
T2 = 30								
	KENNY ME		TOAST JUICE BLANKET SHOE	TELEPHONE	SIT NAP UP	MINE		COLD HOT

(appendix continues)

T3 = 50			SOCK PILLOW POCKET BOOK					
Robert T1 = 10	DADDY MOMMY	DOG CAT TIGER	MILK	Ø	HI	NO	Ø	Ø
T2 = 30	HEIDI I		EYES	CAR GOD THAT IT	SEE DOWN LOOK GO	OH OH BOY OKAY YES THANK-YOU HI	HOT	THERE
T3 = 50	POP POP SCOTT JACKIE HE	BEE	COOKIE JUICE	KEY	IN GOT OUT-SIDE GOING CRY	KNOW WANT	COLD	ALL-GONE HERE

(appendix continues)

Note. [a]Monolingual subject data from Nelson (1973).

[b]English words = UPPER-CASE,

French words = lower-case,

LSQ signs = **UPPER-CASE (bold)**,

Neutral forms = *italics*.

Chapter 5: Conclusion

Origins

The origins of language have remained elusive as a result of questions surrounding the basis of babbling. All normally developing babies proceed through a series of stages of oral and manual development. Around 6 months, reduplicated babbles appear, and motor stereotypies peak. The simultaneity of these developing behaviors thus makes identification of fundamentally linguistic or motoric components of oral or manual acts difficult. Examining the basis of babbling from new perspectives, however, permitted these acts to be differentiated, which in turn shed new light on the origins of language.

In Chapters 2 and 3 the competing motoric and linguistic hypotheses were addressed. In Chapter 2 the basis of babbling was investigated through examining babies acquiring a signed language. A technique yielding quantitative data was employed here for the first time to babies' early linguistic development that, coupled with a technique commonly used in the field, provided the means necessary to distinguish between manual motor stereotypies and manual babbling. In Chapter 3, babies' activity was examined from the oral perspective. A technique previously established in the adult literature was used to dissociate the different types of activity babies produced with their mouths. Despite radically different types of linguistic exposure and employment of techniques, the evidence converges on a single finding: babbling is a behavior fundamentally distinct from other normally developing motor behaviors. This was observed in the babies' production of at least two different types of activity in their respective modes of acquisition, and was captured through original methods and techniques.

Properties

To study and ultimately understand the different types of activity produced by babies, researchers apply a standard set of criteria to babies' acts. The criteria for attributing babbling status, for example, is well-established in the field, and reliably differentiates between babies' early productions which lack true consonants and vowels, and thus syllabic organization, and lexical items which are produced with meaning or reference. In order to draw the conclusion that babbles are linguistic and fundamentally different from other non-linguistic behaviors, however, additional criteria were needed. In Chapter 2, these criteria were established using Optotrak technology which contributed a quantitative property of manual babbles to the criteria for identifying babbles. Moreover, using standard videotape procedures, it was determined that manual babbles were also produced in the linguistic sign-space. This latter property of manual babbling suggests an element of continuity with the adult form of the language.

Similarly, the babies' production of babbles with right mouth asymmetry observed in Chapter 3, support the notion that babbles contain properties identical to the mature form of language. Using a technique adapted from the adult literature it was hypothesized that if babbles were fundamentally linguistic in nature, these adult properties would be present in babies' immature forms. In differentiating between the babbles and nonbabbles produced by babies, it was determined that only babbles were produced under left hemispheric control. This finding is commensurate with those in the field that state that language (including sign language) is lateralized, organized, and processed in the left hemisphere. The findings here therefore suggest that, like manual babbling, oral babbling represents the beginning, or origins, of the expressive language capacity.

Processes

In Chapter 4 the productions of babies acquiring a signed and a spoken language simultaneously were analyzed, previous findings in the literature were confirmed, and new insights into the processes underlying all language acquisition were gained. The findings from previous studies that signed languages are acquired at the same rate and pace as spoken languages were confirmed, despite the fact that the babies studied here were acquiring two languages simultaneously. Further, the bilingual babies constrained, organized, and used their first words, in both languages, and across modalities in ways similar to monolinguals. Specifically, by differentiating between languages, it was discovered that the babies possessed distinct linguistic systems from the onset of lexical productions. By differentiating between modalities, it was determined that common cross-modal semantic and conceptual underpinnings exist. The former observation sheds new light on contemporary issues in bilingualism, including whether babies are "confused" at the outset of language acquisition. The latter point illustrated the differential use that babies make of their input, enabled us to better understand the complex semantic relations underlying the acquisition of meaning in two modalities, and provided evidence that the conceptual scaffolding common to all languages is in place before babies produce their first words.

New Perspectives

In differentiating between the motoric and linguistic acts of babies acquiring a signed or spoken language, a more parsimonious account of language emerges, one that is commensurate with the linguistic hypothesis of the origins of language. The findings from Chapters 2 and 3 regarding the basis of babbling presented here suggest that language emerges as a behavior independent of extant and developing motoric behaviors, and represents the first step in a gradual transition from babbles to first words. The next step, the acquisition of meaning, was evidenced in Chapter 4, in the common semantic and conceptual underpinnings observed as babies make the transition from form to meaning across language and modality. The new perspectives gained in considering the similarities in structure and organization of signed and spoken languages here, and elsewhere, further suggest that this linguistic continuum be expanded to include signed languages. That is, the emergence of language begins at the production of babbles and develops independent of other non-linguistic behaviors and of modality.

In sum, the present thesis contributed new insight to the field of language acquisition in general. Specifically, the research presented herein suggests that babies' babbling is fundamentally linguistic in nature and thus represents the origins of the productive language capacity. Through a collection of new research methods, and the study of a fascinating group of babies, new properties of manual and oral babbling were posited, and processes underlying the acquisition of meaning were elucidated. These methods provided the window through which to examine babies' differentiation of early forms into distinct linguistic and motoric behaviors, and the babies themselves were the lens through which the processes underlying the differentiation of language and modalities were seen.

We were granted insight into our amazing capacity for language, when the world's languages were confused at the Tower of Babel. The cross-linguistic, cross-modal perspectives afforded us coupled with contemporary techniques and methods, together made possible a better understanding of the basis of babbles. And while understanding the nature of the origins of language may not have been what was intended, we were given the means to better define the properties of language through examining these new perspectives. While the people of Shinar were powerless to understand one another given the differences across their languages, it is these same differences that empowered us by providing insight into the processes underlying all of language acquisition. Thus, while parents may still not understand the babbles of their young, through examining the origins, properties and processes of language, researchers are now one step closer to understanding the uniquely human capacity that is the emergence of language.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Permissions Letter

Ref # 02-2563

DATE: Friday, October 18, 2002

TO:

FROM: Karen Lentz, Permissions Assistant
RE: Your request for permission dated 10/17/02

Regarding your request, we are pleased to grant you non-exclusive, non-transferable permission, but limited to print and microform formats only, and provided that you meet the criteria below. Such permission is for one-time use and therefore does not include permission for future editions, revisions, additional printings, updates, ancillaries, customized forms, any electronic forms, braille editions, translations, or promotional pieces. We must be contacted for permission each time such use is planned. This permission does not apply to figures / artwork that are credited to non-AAAS sources. This permission does not include the right to modify AAAS material.

Print the required copyright credit line on the first page that the material appears: "Reprinted (abstracted/excerpted) with permission from [FULL REFERENCE CITATION]. Copyright [YEAR] American Association for the Advancement of Science." Insert the appropriate information in place of the capitalized words.

Permission is limited to the number of copies specified in your request or your first printing.

AAAS must publish the full paper prior to use of any text.

AAAS does not supply photos or artwork. Use of the AAAS material must not imply any endorsement by the American Association for the Advancement of Science. This permission is not valid for the use of the AAAS and/or SCIENCE logos.

Thank you for writing. If you have any questions please call me at or write to me via fax at For international calls, +1 is the country code for the United States.

Headquarters: 5 USA

Permission is valid for use of the following AAAS content only:
Holowka & Petitto, Left Hemisphere Cerebral Specialization for Babies While Babbling, Science 297, 1515 (2002).
For use in: The Emergence of Language—Origins, Properties, Processes

Karen Lentz - Reprint permission

From: IT.EDU>
To:
Date:
Subject:

October 17, 2002

Dear Ms. Lentz,

Please find below the full reference for the article I seek permission to reprint. I wish to reprint the article in full as one of a collection of articles in my doctoral thesis (on which I am sole author) entitled "The Emergence of Language: Origins, Properties, Processes". My thesis will be submitted in the year 2002 to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements of the degree of Doctor of Philosophy. My thesis was written in the Department of Psychology, McGill University at 1205 Docteur Penfield Avenue, Montreal, Quebec, Canada, H3A 1B1.

02-2563

My university requires that "when previously published copyright material is presented in a thesis, the candidate must include signed waivers from the publishers". Thus, I would very much appreciate it if you could send me a signed waiver via the regular post to the address listed below.

Please do not hesitate to contact me should you require any additional information. Thank you very much for your attention to this matter on my behalf.

Sincerely,

Siobhan Holowka

u

****

Title: Left Hemisphere Cerebral Specialization for Babies While Babbling Br 1p

Authors: Siobhan Holowka and Laura Ann Petitto

Page: 1515 (full article)

Journal: Science (print version)

Volume: 297

Date of Publication: 30 August 2002

****

Allison, Malcolm

Subject: FW: Reprint Permission

-----Original Message--
From: Siobhan Holowka [
Posted At: 12 June 2002 23:13
Posted To: Journals Rights
Conversation: Reprint Permission
Subject: Reprint Permission

Please find below the full reference for the article I seek permission to reprint. I wish to reprint the article in full as one of a collection of articles in my doctoral thesis (on which I am sole author) entitled "The Emergence of Language: Origins, Properties, Processes". My thesis will be submitted in the year 2002 to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements of the degree of Doctor of Philosophy. My thesis was written in the Department of Psychology, McGill University at 1205 Docteur Penfield Avenue, Montreal, Quebec, Canada, H3A 1B1.

Sincerelv,

email: s .ca

****

Title: Semantic and Conceptual Knowledge Underlying Bilingual babies' First Signs and Words

Authors: Siobhan Holowka, Francoise Brosseau-Lapr
, and Laura Ann Petitto

Pages: 205-262 (full article)

Journal: Language Learning

Volume, Issue: 52, 2

Year of Publication: June 2002

Permission is granted subject to a full acknowledgement (author, title of the article, the journal / book and ourselves as publisher) on the understanding that nowhere in our text do we acknowledge a previously published source for all or part of this material. 13-6-02

PUBLISHING
BLACKWELL ~~SCIENCE~~ LTD.
OSNEY MEAD
OXFORD
OX2 0EL

August 27, 2002

RE: Signed Waiver from Co-Author, David J. Ostry

Manuscript: Petitto, L.A., Holowka, S., Sergio, L.E., Levy, B., &Ostry, D.J. (under review). Baby hands that move to the rhythm of language: Hearing babies acquiring sign languages babble silently on the hands. *Cognition.*

In my capacity as co-author, I hereby grant Siobhan Holowka de Belle permission to include the manuscript referenced above in her manuscript-based doctoral thesis entitled "The emergence of language: origins, properties, processes".

Sincerely,

David J. Ostry

Dartmouth College HANOVER · NEW HAMPSHIRE ·
Department of Psychological and Brain Sciences

July 22, 2002

RE: Signed Waiver from Co-Author, Dr. Laura Ann Petitto

Manuscript: Holowka, S. & Petitto, L.A. (In Press). Left Hemisphere Cerebral Specialization For Babies While Babbling. *Science*.

In my capacity as co-author, I hereby grant Siobhan Holowka de Belle permission to include the manuscript referenced above in her manuscript-based doctoral thesis entitled "The emergence of language: origins, properties, processes".

Sincerely,

Dr. Laura Ann Petitto

Dartmouth College HANOVER · NEW HAMPSHIRE ·

July 22, 2002

RE: Signed Waiver from Co-Author, Dr. Laura Ann Petitto

Manuscript: Holowka, S., Brosseau-Lapré, F. & Petitto, L.A. (2002). Semantic and Conceptual Knowledge Underlying Bilingual Babies' First Signs and Words. ***Language Learning, 52(2),*** **205-262.**

In my capacity as co-author, I hereby grant Siobhan Holowka de Belle permission to include the manuscript referenced above in her manuscript-based doctoral thesis entitled "The emergence of language: origins, properties, processes".

Sincerely,

Dr. Laura Ann Petitto

July 16, 2002

RE: Signed Waiver from Co-Author, Françoise Brosseau-Lapré

Manuscript: Holowka, S., Brosseau-Lapré, F. & Petitto, L.A. (2002). Semantic and Conceptual Knowledge Underlying Bilingual Babies' First Signs and Words. *Language Learning, 52(2),* 205-262.

In my capacity as co-author, I hereby grant Siobhan Holowka de Belle permission to include the manuscript referenced above in her manuscript-based doctoral thesis entitled "The emergence of language: origins, properties, processes".

Sincerely,

Françoise Brosseau-Lapré

Dartmouth College HANOVER · NEW HAMPSHIRE

July 22, 2002

RE: Signed Waiver from Co-Author, Dr. Laura Ann Petitto

Manuscript: Petitto, L.A., Holowka, S., Sergio, L.E., Ostry, D.J. & Levy, B. (under review). Baby hands that move to the rhythm of language: Hearing babies acquiring sign languages babble silently on the hands. *Cognition.*

In my capacity as co-author, I hereby grant Siobhan Holowka de Belle permission to include the manuscript referenced above in her manuscript-based doctoral thesis entitled "The emergence of language: origins, properties, processes".

Sincerely,

Dr. Laura Ann Petitto

July 25, 2002

RE: Signed Waiver from Co-Author, Bronna Levy

Manuscript: Petitto, L.A., Holowka, S., Sergio, L.E., Ostry, D. & Levy, B. (under review). Baby hands that move to the rhythm of language: Hearing babies acquiring sign languages babble silently on the hands. *Cognition*.

In my capacity as co-author, I hereby grant Siobhan Holowka de Belle permission to include the manuscript referenced above in her manuscript-based doctoral thesis entitled "The emergence of language: origins, properties, processes".

Sincerely,

Bronna Levy

August 16, 2002

RE: Signed Waiver from Co-Author, Lauren E. Sergio

Manuscript: Petitto, L.A., Holowka, S., Sergio, L.E., Levy, B., &Ostry, D. (under review). Baby hands that move to the rhythm of language: Hearing babies acquiring sign languages babble silently on the hands. *Cognition.*

In my capacity as co-author, I hereby grant Siobhan Holowka de Belle permission to include the manuscript referenced above in her manuscript-based doctoral thesis entitled "The emergence of language: origins, properties, processes".

Sincerely,

Lauren E. Sergio