Early Language Acquisition in Humans: A Review of the Babbling Literature

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Abstract

The study of human infant vocal behavior has grown substantially in recent years and much is now known about the acquisition of speech and language in the early years of life. However, several outstanding questions remain. Among these is: What is the role of babbling in the infant? Models of speech in which babbling plays a central role have been proposed. However, these models typically ignore basic facts about infant babbling. The purpose of this paper is to summarize some of the existing literature on babbling as a prelude to subsequent modeling efforts. Computational models of speech and babbling will not be review here.

1 Introduction

Babbling is a stereotyped behavior that precedes or accompanies motor skill acquisition in animals. Little is known about the mechanisms or role of babbling. The term "babbling" is often taken to be synonymous with "vocal babbling". In this paper, the term babbling will refer to vocal babbling in humans unless otherwise stated.

Roman Jakobson (1941/68) postulated that (1) babbling and meaningful speech are distinct processes, (2) babbling has astonishing diversity, and (3) babbling has little or no regularity (i.e., it is random). In the past two decades, many researchers have studied babbling in human infants and have found that some of Jakobson's ideas need to be reconsidered in light of the data. This paper summarizes literature on human vocal behavior during the first two years of life, with an emphasis on babbling.

While infants exhibit a diverse vocal repertoire during the babbling and first words phases, we will see that they also exhibit considerable regularity. Thus attempts to model babbling as a random process are not given support by the large literature on babbling. Moreover, the vocal repertoire during babbling, while large, is but a small subset of that seen in adult language (as opposed to the common view that babbled sounds are a superset of adult productions). Infants acquire new productions (phonemes) only very slowly as the demands of word acquisition are imposed, and often make due with sounds from their babbling repertoire to create quasi-words, and imitate (as best they can) words from their target language. By the same token, the babbling literature also makes it clear that babbling and meaningful speech are not distinct processes. This is especially clear when considering studies of infants in the late babbling stage during which they are acquiring

their first words. There is both phonological and phonetic continuity during this period, making it very difficult even to define separate stages of babbling and word acquisition.

On the question of environmental influence on the development of language, the literature provides mixed answers. Mother's speech plays a role, but cross-cultural differences do not seem to affect the onset of babbling or its content. Most significantly, linguistic environment does not seem to affect the babbling repertoire. The literature demonstrates that the babbling repertoire of infants from such divergent linguistic environments as English, French, Thai, Chinese, and Dutch all are phonetically very similar. Differences emerge only slowly, usually beginning with vowels, and only later are differences in consonants learned.

In general, the onset of babbling in normal infants is robust, occurring sometime between 7-10 months of age (always by 10 months). This is even true in mentally retarded infants, and premature infants. On the other hand, auditory feedback (or "tactile speech", in the case of acochlear infants), is required for the onset and continuance of babbling. But it is not clear whether the infant must hear the speech of others, or whether it is the infant's own speech that is required for the onset of babbling (See Locke and Pearson, 1990, on tracheostomized infants).

Maturational theories of babbling have received some support from studies that examine the relationship between the onset of babbling and the onset of unimanual right-handedness.

While our knowledge of babbling and early language acquisition have grown tremendously in recent years, many questions remain. Some of these questions are: What is the role of feedback (visual, auditory, or tactile) in the onset of babbling and the development of speech? How does linguistic environment influence the late babbling and first words stages? To what extent are babbling and language innate? Perhaps the most important question is: What role does babbling serve in the acquisition of speech and language? It seems clear that the time is right for a theoretical synthesis that might address some or all of these questions.

The following sections present data on pre-canonical babbling, canonical babbling, late babbling, and acquisition of first words.

2 Meta Issues

Before looking at particular data, it will be useful to consider several larger themes and issues present in the babbling literature.

2.1 Approaches to the study of Babbling

All normal infants babble during the course of language acquisition. In recent years, the interest in babbling research has increased dramatically, and an interdisciplinary approach is often employed.

Four basic forms of study are prevalent in the literature:

(1) acoustic analysis: Vocal babbling gives rise to acoustic output which may be analyzed. Many regard babbling as a precursor to speech, and, therefore, babbling sounds are often analyzed with the intention of finding the similarities and differences between babbled sounds and similar speech sounds adult speech. Many of the studies count occurrences of adult-like sounds in the babbled output. Such an approach clearly calls for a metaphonological classification system that is gradually gaining acceptance.

In addition, the developmental continuity in the babbled sounds is of great interest.

(2) functional analysis: What is the functional role of babbling? One paper suggested that babbling serves to train the auditory system (Losik, 1988), using repetitions to provide information on the variabilities likely to be encountered in speech. Losik suggested that auditory development is impeded if babbling is blocked, and observed that babbling occurs mainly during periods of silence in the infant's environment, an observation that has been implied by other researchers. The dominant view, however, is that babbling is a necessary precursor of speech production, and is not necessary for auditory development. If babbling is a precursor of speech, then late babbling and acquisition of first words should overlap to some extent. (For a comparison of homonymy and reduplicated babbling, see Lleo, 1990.)

(3) developmental: To what extent is babbling just a manifestation of cell growth or other anatomical and physiological changes occurring in the infant? The relationship between babbling and acquisition of various motor skills has been studied (Hay, 1984; Ramsay, 1984; Ramsay & Willis, 1984).

(4) theoretical: Elbers (1982) asks: During babbling, "what exactly is the child doing?". Elbers provides a brief summary of the existing babbling theories. They are (i) learning

theory, in which the infant is trying to acquire sounds resembling those of the caregiver, (ii) maturational theory, in which babbling is primarily the result of biological maturation, that it is only a "side effect", (iii) the continuity approach, an extension of learning theory, in which the sounds of babbling gradually merge into early speech, (iv) the discontinuity approach, an extension of maturational theory, in which speech may occur in the infant after maturation has completed, and (v) the cognitive approach, advanced by Elbers, which combines the best features of the other approaches.

2.2 The Stages of Vocalization

Many different classification schemes have been used to identify the stages of vocal development (Koopmans vanBeinum & van der Stelt, 1986; Elbers, 1982; Roug, Landberg, & Lundberg, 1988; Mitchell & Kent, 1990; Smith, Brown-Sweeney, & Stoel-Gammon, 1989). Indeed, most studies of babbling suggest a progression of developmental stages. While there is currently no universally recognized sequence of infant vocalization stages, a typical classification scheme consisting of the following stages is often implicitly or explicitly used: (1) gooing and cooing, (2) reduplicative babbling, (3) variegated babbling, (4) late babbling, (5) first words.

Elbers (1982) has suggested the following scheme: (1) prerepetitive period, (2) repetitive stage, (3a) concatenating stage a (babbles share same place of articulation but differ in manner of articulation), (3b) concatenating stage b (babbles have different place of articulation), (4) mixing stage (in which concatenations are more varied or 'mixed') (Elbers, 1982). Typically, the highest percentage of non-transcribable babbles occur in the prerepetitive stage and the mixing stage.

A detailed study of the stages of infant vocalization prior to the onset of canonical babbling has been conducted by Koopmans vanBeinum and van der Stelt (1986) (see the Pre-Canonical Babbling section below).

2.3 Infant Motor Development

Hay (1984) provides a nice summary of motor development in humans. Among many other interesting features of motor development presented by Hay, evidence is presented that motor development is nonmonotonic. That is, reflexive behaviors seen very early in infancy typically disappear, to reappear later under voluntary control. This is seen in the development of handedness. Ramsay (1984) and Ramsay and Willis (1984) have

shown that infants begin to demonstrate unimanual right handedness on the week of babbling onset, whereas they do not show any preference on preceding weeks. The infants demonstrate a temporary loss of this hand preference shortly after babbling onset. Ramsay argues that this may reflect stages in the expression of hemispheric specialization. Onset of babbling was determined by the parent and was defined, for this study, as the week after which infants continued babbling syllables for 8 consecutive weeks. Of the 30 infants studied, only 5 started babbling, and later stopped before the 8 week criterion had been met. Ramsay reports that a similar phenomenon is thought to occur earlier. In particular, newborn postural and manual reflexes, which are related to later hand preferences in older infants and children disappear by the second or third month of life, during which the first cooing vocalizations arise.

Peter MacNeilage and Barbara Davis have also worked extensively on the analysis of infant sounds and have suggested a theoretical framework for understanding babbling in the context of unimanual and bimanual handedness and the evolution of the primate brain (MacNeilage, 1986; MacNeilage & Davis, 1990).

Mayes and Zigler (1992) found that 9-11 month old infants showed positive affective responses ("smiling, babbling, and laughing") while attempting to master various age-appropriate motor tasks such as pulling to stand, standing with support, and taking steps with support. In this study, the vast majority of the babbling was done while the infant was alone (away from the adult or observers). Other researchers have also reported that happy infants are more likely to babble when left alone with a toy.

2.4 The role of oral and other types of feedback

In order for speech and language to develop, several types of feedback must be provided to the infant. Auditory input and feedback seem to be required for normal onset of babbling and subsequent development of speech (see the section on deaf infants below). But it is likely that several types of oral feedback are also required. This issue has not been studied in infants. However, related studies in adults may suggest a role for oral feedback in early language acquisition.

Oral feedback includes both tactile, and proprioceptive feedback. In studies with adults who received a bilateral mandibular nerve block, Borden, Harris, and Oliver (1973) found that prominent distortions of speech quality occurred only in /s/ clusters. Borden (1979) claim that the interference is with taction, not proprioception. It would seem, then,

that taction is not necessary for production of speech. Attempts to block proprioceptive feedback showed that, for large jaw changes at least, spindle feedback (proprioception) was necessary. See also Borden (1980).

3 Pre-Canonical Babbling

Prior to the onset of canonical babbling (which occurs at 7-10 months of age in normal infants), the infant is capable of producing a variety of vocal sounds.

Koopmans vanBeinum and van der Stelt (1986) studies this stage in the development of the infant. 69 infants were studied based on written survey of their parents. Comfort sounds, which can be reliably identified by adults, are used to study infant vocalizations. Milestones are identified for phonation, articulator position, and articulator movement. An infant was assigned to a stage if two attributes of that stage were present. Most infants could be assigned to a stage every two weeks during the study. Koopmans vanBeinum and van der Stelt (1986) concluded that: (1) Each infant goes through six different stages. (2) By stage 5, all motor elements of adult speech are present, at least in rudimentary form. (3) Infants of the same age can belong to totally different developmental stages.

4 Canonical Babbling

This section discusses canonical babbling, the onset of canonical babbling, and variability of sounds during babbling, both within an infant, across infants within a single language environment, and cross-linguistically.

The term *babbling* is often associated with production of repeated CV syllables such as "bababa" and "dadada". Such a production, (CV, CVCV, or CVCVCV) is referred to as a *babble*. *Reduplicative babbling* refers to production of a babble in which the same (or nearly the same) consonants and vowels occur. In *variegated babbling*, the consonant or vowel differs during a babble. *Canonical babbling* usually implies either reduplicative or variegated babbling.

The study of canonical babbling is important for what it might teach us about speech, language, and developmental processes. The study of canonical babbling may also find application in the diagnosis of various kinds of speech disorder. One study (Stoel-Gammon, 1989) focussed on two infants, out of 34 infants studied from 9 to 24 months, whose speech skills were below criterion levels at 24 months of age. It was found that these two "late talk-

ers" had unusual patterns of babbling from 9 to 21 months of age. While Stoel-Gammon (1989) are cautious in their conclusions, they suggest that "[atypical babbling] may be *one* of many possible contributing factors" to the delay of language acquisition [emphasis in original].

4.1 Metaphonology

It is traditional, in the study of speech, to transcribe an utterance according to the phonemes defined by the international phonetic alphabet (IPA). However, such a transcriptional approach assumes that the infant vocalizations correspond to adult speech. This is not always the case. Indeed, it is possible for a transcriptional analysis to render a bird call as a human language syllable, even though bird calls generally consist of poorly formed consonants and vowels.

On the other hand, an acoustic (instrumental) analysis of an infant's vocalizations yields quantitative and objective measures such as fundamental frequency, formant frequencies and transitions, durations, etc. However, it is difficult to relate such measures to adult speech, which is one of the goals of the study of infant babbling.

Each approach has its advantages and disadvantages. Oller (1980, 1986) defined a metaphonological scheme allowing for the transcription of well-formed and marginal syllables of speech. This metaphonology specifies the ranges of acoustic parameters necessary for this transcription, and it has been widely adopted in the literature.

In a metaphonological framework, canonical babbling implies the production of well-formed syllables. Prior to the onset of canonical babbling, an infant produces marginal babbles or syllables. A *marginal* syllable "has a well-formed margin (consonant) and nucleus (vowel), but includes a slow (usually $>$ 120ms) formant transition" (Eilers, Oller, Levine, Basinger, Lynch, & Urbano, 1993).

4.2 Onset of Babbling

Virtually all normal infants begin canonical babbling by 10 months of age, but there is wide variability.

As a result of Oller's (1980, 1986) work on metaphonology, it is necessary to revisit earlier studies (which did not use the metaphonology) if they were concerned with the age of onset of canonical babbling or characterizations of pre-canonical vocalizations. Thus, in the literature before 1980, we find several studies that claim that the onset of canonical

babbling occurs between the ages of 5 and 7 months. Now, one seldom finds a claim for an onset of babbling any earlier than 7-10 months.

A variety of methods have been reported for determining the onset of babbling. In most studies, the researcher visits the child in the home and records spontaneous vocalizations while the child plays alone with toys, or during interaction with the mother. The recordings are transcribed. The visits typically occur once every week.

In Eilers et al. (1993), a more accurate method is used to obtain the age of onset of babbling. The child and a parent visit the laboratory at least once each month from the age of 1 month onwards. From 4 months onward, the staff notes whether marginal babbles are being produced. If so, the parents are asked to be especially vigilant and call immediately when the first canonical babbles appear. The parents are trained to recognized canonical babbles. At this point, the staff call the parents biweekly to ensure that the parents are monitoring the child's progress. When the parents call with the report that the child is producing canonical babbles, the child is brought into the laboratory on each of five consecutive days (excluding weekends) for confirmatory tests. An infant is said to be in the canonical stage only if repeated occurrences of canonical syllables were observed during a majority of the five consecutive laboratory visits after the parental report of canonical babbles.

4.3 Acoustic Features of Babbled Sounds

Many researchers have studied the acoustic features of babbled sounds (Mitchell & Kent, 1990; Kent & Murray, 1982; Davis & MacNeilage, 1990; Roug et al., 1988; Elbers, 1982).

For example, Roug et al. (1988) studied place of articulation, manner of articulation, degree of vowel opening, and assigned babbles to "phonotactic categories" for infants from 1 to 20 months of age. They found that, of the 11 types of place of articulation recognized by the IPA, 92% of the babbles were one of four types: bilabial, dental-alveolar, velar, and glottal; while 4% were palatal, 3% were uvular, 1% were labiodental, and 0% were all of the remaining 4 types of place of articulation. Of the four infants in the studied, three initially produced mostly glottal consonants. In addition, they observed variability among and within infants across the age range studied.

The same study also looked at manner of articulation, 9 of which are recognized by the IPA. They found that the infants in the study produced predominantly stops, nasals, and fricatives (91%); and few of the others: semi-vowel (4%), lateral (3%), trill (2%), the

remaining three (0%).

Roug et al. (1988) also studied the vowels and found that the vast majority of the vowels were the /a/ in far, the /ae/ in cat, the /e/ in met, the /u/ in but, the /e/ in gate, and the /i/ in bit. An insignificant number of the other vowels recognized by the IPA were observed during this study.

4.4 Reduplicated versus Variegated Babbling

A reduplicated babble is a CVCV production in which the second CV consists of the same phonemes that are present in the first CV. A variegated babble is a CVCV production in which the C or the V is different in the second syllable. Early studies of babbling held that these two types of babble were produced by the infant during different stages, namely, the reduplicated babbling stage and the variegated babbling stage. Smith et al. (1989) suggest, however, that this is not the case. They studied 10 infants at four month intervals from 6-18 months of age. They show that the number of reduplicated babbles actually rises slightly until the age range 10-13 months when it begins to fall, finally dropping below the rate of variegated babbling at about 14 months of age. In contrast, the rate of production of variegated babbles falls slightly until 10-13 months of age, when it then starts to rise. By 14-17 months of age, the rate of production of variegated babbles is larger than the rate of reduplicated babble production, but at no time (before 17 months) does the production of reduplicated babbles cease.

Similar results were obtained by Mitchell and Kent (1990) who referred to these two "stages" as *repetitive* and *nonrepetitive* babbling. They obtained data on the proportion of changed place of articulation and changed manner of articulation.

4.5 Cross-Linguistic Effects in Babbling

Some features of infant babbling are found to be the same across linguistic environments while others differ. (De Boysson-Bardies, Bacri, Sagart, & Poizat, 1981; De Boysson-Bardies, Sagart, & Bacri, 1981; De Boysson-Bardies, Sagart, & Durand, 1984; De Boysson-Bardies, Sagart, Halle, & Durand, 1986; De Boysson-Bardies, Halle, Sagart, & Durand, 1989; De Boysson-Bardies & Blake, 1992; Oller & Eilers, 1982). In particular, the consonant repertoire is very similar across linguistic cultures. Consonant frequencies obtained with French infants were similar to those obtained for English and Thai infants (De Boysson-Bardies et al., 1981). But by 10 months, infant vowels are more likely to share many

features with vowel counterparts in the target language (De Boysson-Bardies et al., 1989).

These results are of interest because they suggest that early linguistic experience (from birth to the onset of babbling) does not affect the babbling of consonants; it is only after babbling has begun that the infant begins to shape the consonant sounds. Moreover, it suggests that babbling of consonants is innate and is triggered, but not modified, by auditory input.

In later studies, some effects due to linguistic context have been seen, especially in relation to vowel formant frequencies and variability. Levitt and Utman (1992) found that American and French infants produced vowels with different formant frequencies and variability from 5 months of age onward, suggesting that linguistic experience affects the earliest babbled vowels. They also found adjustments in duration of final and non-final syllables that reflect trends in the infant's target language. However, the study considered only two infants, one from each language environment.

In addition, it seems that initial babbling of voicing contrasts (VOT) does not vary with early linguistic experience. Eilers, Oller, and Benito-Garcia (1984) found that there was no significant difference in the distributions of VOTs for Spanish and English learners at 1 year of age whereas half of the infants had learned the VOT distributions present in their target language by age 2 years.

Taken together, these results may suggest that babbling of sounds that require fine temporal control may not benefit from early linguistic experience whereas babbling of continuants benefits from such experience.

5 Late Babbling and First Words

De Boysson-Bardies et al. (1981) define a *babbled utterance* as "consisting of at least one syllable wherein a consonantal element (i.e. syllable margin) can be identified", and *late babbling* to occur "when a child's utterances consist of isolated syllables or longer sequences of articulated syllables which are grouped under an intonational or pitch contour roughly similar to that of a sentence of the language". They inquire whether the articulatory nature of babbling is related to the phonological structure of the language, and note that there has been a widespread view among linguists that these are unrelated. They cite, for example, Moskowitz (1970), who writes: "By the late babbling period ... there are only *random* strings of babbled sounds ...".

A variety of studies of late babbling have focused on different aspects of language

acquisition: the continuity hypothesis (Locke, 1989; Kent & Bauer, 1985; De Boysson-Bardies et al., 1981, 1981), first words: (Blake & Fink, 1987; Vihman, Ferguson, & Elbert, 1986; Elbers & Ton, 1985), play pen monologues: (Elbers & Ton, 1985), and parent reference (the selection of words to denote 'mother' and 'father'): (Locke, 1985; Elbers, 1986).

5.1 The continuity hypothesis

In late babbling, the infant typically has a large repertoire of sound, but the repertoire is only a subset of the set he will have at later stages. Moreover, this subset is very similar across linguistic environments.

De Boysson-Bardies et al. (1981) studied a French boy who was recorded weekly for 45 minutes each session from 1;6 to 1;8. The sequences were transcribed using the IPA. The consonant frequencies obtained were very similar to consonant frequencies obtained in other studies conducted with French infants. The labials were mostly bilabials. Even bilabial fricatives outnumbered labiodental fricatives. In general, the hierarchy in frequency of points of articulation is: dental > labial > velar > alveo-palatal. In addition, the infant showed a range of VOT from long lead to short lag types. Fricatives are either voiced throughout or unvoiced, but never aspirated. Nasals are voiced throughout. There are more front vowels than back vowels. These results concur with those obtained by others for French and other linguistic environments.

In order to investigate the transition from babbling to late babbling, both longitudinal and cross-sectional studies can be done. In the case of a cross-sectional study, it is necessary to compare the results to those obtained in other cross-sectional studies done at other ages. This was the approach taken by Kent and Bauer (1985) who recorded 13 month-old infants and found general agreement with studies for younger and older children, suggesting that overall continuity is maintained in early phonetic development.

5.2 First Words

Several studies have explored the relationship between babbling and the acquisition of the first words (Blake & Fink, 1987; Vihman et al., 1986; Elbers & Ton, 1985). Infants do not typically stop babbling when they begin producing words, and the words are highly idiosyncratic. Elbers and Ton (1985) suggest that the source of this idiosyncrasy "might be found in the child's speech-concurrent babbling". They also suggest that language acquisition may serve a dual role for the infant. Not only does language equip the child

with language, but the child may also work on language acquisition for its own sake. To study these issues, Elbers and Ton (1985) recorded the play-pen monologues of a 1-year-old Dutch boy for 20-30 minutes each day while he played in his play-pen, for a period of six weeks. Prior to the study, the child had acquired two word-like forms and one word. The mother kept a diary and noted occurrence of new words. During the study, the infant acquired 4 new words, and it was found that prior babbling "prepared for" the selection and production of these words. Prior studies suggested that children generally avoid using more than one place of articulation in their early words, but the boy acquired such a word, [pa:t(uh)], during the fourth week of recording. Vowel characteristics were not considered in this study.

Stoel-Gammon and Cooper (1984) studied three infants from the beginning of the late babbling stage through the acquisition of the first 50 words. Their goal was to study the relationship between word acquisition and phonological development. They distinguished between (1) babbling (no consistent sound-meaning relationship), (2) acquisition of adult words (i.e., identifiable based on adult word), and (3) creation of child-based "quasi-words" (having consistent sound-meaning relationship, but not based on adult model). They noted that several of the phones produced by the infants during babbling are not phonemes of English, and therefore, they will never appear in real words. They conclude that an infant uses a limited number of "patterns" in the first words. These results directly challenged several of Jakobson's claims about the acquisition of language.

5.3 Parent reference

Locke (1985) notes that a number of investigators have reported that there is a tendency for words for 'father' to appear earlier than words for 'mother'. Such "sex" references are common across cultures. For example, a Slovenian infant will produce 'ata' earlier than 'mama'. A Czech infant produces 'tata' before 'mama'. In English, 'dada' is produced before 'mama'. Locke (1985) summarizes a number of studies on the learning of words and concludes that "children aged 1;4 to 1;10 were significantly more likely to *attempt* the name of an object if it contained sounds the children were able to say". Many infants render 'papa' as 'baba' because they may, in fact, perceive [b]s and [d]s as voiceless, unaspirated stops. Also, infants "are more likely to say a bilabial or an alveolar stop than they are to say a bilabial nasal". Only about 10% of infants have a preference for producing bilabial nasals.

Elbers (1986) offers a different explanation for the tendency to produce 'father' words

earlier. Elbers claims that the literature is replete with examples in which nasals are commonly produced by infants in the context of crying, whining, whimpering (fussing). Elbers cites a study in which infants use 'mama' as a lament or a general request *before* they use it in a referential way. Thus, mothering and 'mama' go together.

6 Handicapped Children

The study of normal infants provides a wealth of data and insights into the workings of speech in general and babbling in particular. However, additional insight can be obtained from the study of infants having problems that impair the speech perception or production mechanisms.

There is a large literature on language acquisition in blind infants. However, no attempt was made to study that population for this review. See the collection edited by Mills (1983).

6.1 Deaf Children

A number of studies considered the effect of deafness on onset of canonical babbling and babbling content (Stoel-Gammon & Otomo, 1986), (Kent, Osberger, Netsell, & Goldschmidt-Hustedde, 1987; Oller & Eilers, 1988; Oller, Eilers, Bull, & Carney, 1985; Stoel-Gammon, 1988). It is difficult to analyze this data because there is so much variability in the degree of deafness among deaf infants. Even profound deafness can be partly mitigated with sufficient amplification (see the section below on acochlear infants).

The main results from these studies are that (1) the onset of babbling is delayed in hearing-impaired infants. Babbling onset will not commence in the case of total deafness until some form of tactile feedback is provided. (2) The babbling ratio (the average number of canonical babbles per utterance) is significantly lower in hearing impaired infants.

This research has great clinical significance and is generating a large literature. It also is very important for the modeling of speech processing and babbling.

6.2 Acochlear Children

There is not a lot of data on acochlear children in relation to babbling since these children are hard to identify at an early enough stage. It is difficult to tell the difference between a child who is merely profoundly deaf (but whose hearing can be improved with amplification) and an acochlear child (who cannot hear even with amplification).

Lynch, Oller, and Steffens (1989) have studied a male child who was 27-42 months of age during the study. The subject's mother reported that he was not saying words, but did make sounds. It was noted clinically that he produced only small numbers of developmentally primitive utterances, consisting primarily of quasiresonant sounds. Three different tactile vocoders of different type were tested in this study. The subject received a total of about 24 hours of exposure to tactile "speech" input with a Tacticon 1600 (which the subject found aversive) and about 208 hours of exposure to tactile "speech" input with a Tactaid II (which the subject readily accepted). The Tacticon 1600 uses small electrical signals placed about the abdomen to code 16 frequency channels. The Tactaid II uses a vibrator placed at the sternum to code 2 frequency channels.

Onset of canonical babbling occurred at 29-31 months ("determined by a 0.2 or greater ratio of canonical syllables to utterances" where utterance is defined in a manner related to a musical phrase). In the Lynch et al. (1989) study, the child produced a large number of reduplicated sequences in the following months up to 42 months of age. The authors were surprised that canonical babbling occurred at all. This study showed that auditory input is not necessary for the onset of babbling, but that some form of feedback correlated with the speech signal is required.

6.3 Mentally Retarded Children

Two of the papers specifically studied the speech of infants with severe learning disabilities (Oller & Smith, 1981; Oller & Seibert, 1988). Oller and Seibert (1988) examine a broad cross-section of 36 mentally retarded infants, some with unknown etiologies, and the others with various combinations of Down syndrome, seizure disorders, motoric disorders, microcephaly, dysarthria, autism, hydrocephalus, hearing impairment, visual impairment, and "failure to thrive". Data from 11 nonretarded infants was compared to the retarded group. Three speech samples from each infant were recorded at 5, 6, and 11 to 13 months. Utterances were defined to roughly correspond to the linguistic notion of "breath-group". A pause of one second or more between sounds was taken to indicate an utterance boundary. The basic conclusion was that prelinguistic retarded children produced canonical syllables, but many of then did not produce as many per utterance as nonretarded children. On the other hand, 17 of the retarded infants had a normal canonical babbling ratio (the number of canonical syllables per utterance). Children with Down syndrome showed relatively little handicap in terms of babbling. In addition, there appears to be a correlation between canonical babbling ratio and development of meaningful speech.

6.4 Down's Syndrome Children

In a study devoted exclusively to a Down's syndrome, Oller and Smith (1981) compare vocalizations in normals and Down's syndrome infants. In general, speech and language performance of Down's syndrome children show a considerable lag compared to normals. In previous studies, there were no significant difference in the (1) frequency of emission and length of utterances and (2) the number of different vowel and consonant types between normals and Down's syndrome infants (age 9-13 months). However, earlier studies did not pay attention to metaphonological issues and so the measurements provide, at best, a gross metric. In the present study, Oller and Smith (1981) look at onset of reduplicative babbling. In normals, this happens within the age range of 6-9 months. Down's infants with normal hearing were recorded during one-half-hour sessions at least once every three months (yes, months). The average age of reduplicative babbling onset by this technique was found to be $8\frac{1}{2}$ months. Moreover, the frequency of occurrence of consonants followed the same time course over the age range from 0-3 months to 18-21 months.

6.5 Tracheostomized Children

Infants with obstructed or underdeveloped respiratory systems sometimes require a tracheostomy, in which a hole is made in the trachea, just below the larynx, and a tube (cannula) is placed in the opening. Locke and Pearson (1990) studied a single infant, Jenny, who was tracheostomized after several months of intermittent intubation from 0;5-1;8. She was otherwise normal. The purpose of the study was to determine to what extent she would vocalize after decannulation. Prior studies with tracheostomized infants who were decannulated 'prelinguistically' were found to exhibit no delay in the acquisition of language, leading some authors to question the necessity of babbling for language development. It was later found that a longer period of tracheostomy led to greater subsequent phonological impairment. Attempts to teach Jenny to sign at 1;9 failed. There was little evidence that Jenny used signs referentially, though she was able to mimic up to 19 different signs. By occluding the stoma (the hole in the trachea), Jenny was able to phonate. Eight recording sessions occurred during the tracheostomy, and four sessions occurred within a month after decannulation. She produced little vocalization before decannulation. After decannulation, she vocalized much more and used a few words. In addition, she bypassed the sequence from velar to alveolar place of articulation, and jumped immediately to the place of articulation appropriate for her age (labial). Locke and Pearson (1990) suggest

that the language delay resulted from Jenny's failure to learn that her own voice could be used referentially. This is a theme that others have also expressed.

6.6 Cri Du Chat

Cri du chat is a rare genetic defect in which the infant produces a "catlike" cry present from birth until late in life. Other symptoms include low birth weight, microcephaly, hypertonia or hypotonia, round faces, and severe developmental delays. Some researchers argue that the catlike cry results from abnormalities of the larynx, while others argue that it relates to central nervous system dysfunction. There are reports of substantial delays in acquisition of spoken words. In one study, only $\frac{1}{2}$ of the subjects having the disorder acquired language by age 23 years. Sohner and Mitchell (1991) performed a longitudinal study with one subject, age 8-26 months, and found that the onset of reduplicative babbling was not noted until 13 months.

6.7 Premature Birth Children

Premature infants offer the opportunity to test several hypotheses of language and speech development. For example, does early auditory exposure have an accelerating effect on development of speech-like sounds? Eilers et al. (1993) review the literature of human and nonhuman auditory and vocal development of normal and preterm animals. They observe that the unborn receives only bone- and fluid-conducted, low-frequency acoustic stimulation. Eilers et al. (1993) studied 20 preterm infants longitudinally. The equivalent chronological age (CHA) and corrected age (CA) was determined for each infant. It was found that the onset of canonical babbling in preterm infants occurs occurs later using CHA, but earlier using CA. The onset age difference was about 4 weeks using CA. This result tends to support the conclusion that increased and earlier auditory stimulation and feedback have a significant effect on the onset of canonical babbling.

7 Social Interaction and Babbling

Social interaction certainly plays a role in the infant's acquisition of speech. A number of studies have examined this issue in both prelinguistic and linguistic infants: mother's speech (Toda, Fogel, & Kawai, 1990); sibling speech (Dunn & Kendrick, 1982); various conditioning paradigms (Hamilton, 1977); and learning the rules of communication (Ninio

& Bruner, 1978).

Cross-cultural differences in mother's speech: What is the role of the mother's speech at an earlier stage in the development of the infant's speech? To examine this question, Toda et al. (1990) studied the interactions between a mother and her infant. Both Japanese and American mother/infant pairs were studied. They hypothesized that maternal speech serves two purposes: (1) as input for language acquisition, and (2) as socialization for culturally appropriate communication. They found that US mothers tend to respond to and stimulate infants' positive vocalization, whereas Japanese mothers show less vocalization, physically contacted the infant more, and were more likely to respond to infants' negative vocalizations. The study only examined 3 month old infants.

Toda et al. (1990) found that maternal speech to prelinguistic infants is more complicated, more conversational. Maternal speech to infants who were using words was slower and more simplified, perhaps in order to help teach the infant. It was found that "there was no difference in the amount and temporal pattern of 'gaze at mother' between the countries", and "no difference were found in the frequency and duration of gaze at mother". Thus although there are cultural differences between the American and the Japanese mothers in their interaction with their infants, there were no significant difference in the pattern of gaze during mother/infant communication.

Conditioning paradigms: Hamilton (1977) examined the effect of operant conditioning on the learning of vowel and consonant sounds and short words. In previous studies, it was found that adult repetition of an infants sound, sometimes changed in the direction of correct adult usage, "increased vocalization rates more than the use of touch or food reinforcement did". Hamilton (1977) used four test conditions consisting of (1) operant conditioning (verbal rewards for correctly produced sounds), (2) vocal imitation (the experimenter vocally imitates the infants utterances), (3) modeling (the experimenter produces the target sound several times for the infant), and (4) modeling and social reinforcement (same as modeling except experimenter rewards with smiles and verbal rewards), and a control condition. There was little difference between the control group and the operant conditioning group in the number of emitted sounds and words. The modeling and social reinforcement group showed higher performance on word production, but not on consonants and vowels.

Learning rules of communication: Although not directly relevant to the problem of babbling, learning rules of communication plays an important role in language acquisition. The work of Ninio and Bruner (1978) is mentioned to prevent the reader from drawing the

mistaken conclusion that word acquisition by the infant just *happens*, but instead results from an active interaction with others skilled in the target language. Ninio and Bruner (1978) study mother-infant dyads in the period between 0;8 and 1;6 involved in a ritualized dialogue of picture-book reading. Prior studies have shown that 64% of a child's 50-word vocabulary consists of nominals (names of people and objects), and children seem to "take great delight" in naming objects. The child is *seen* by the mother as having the intention to point at or name a specified object in a picture-book reading environment, and it is suggested that "the child finds out by the responses of adults what he is assumed to mean by what he is saying". Thus, a "scaffolding dialogue" ensues between the mother and the child during which the child learns the labeling of objects and the rules of turn-taking.

Mimicry: The ability and tendency of infants to mimic other humans in the environment is of great theoretical interest. It is well known that infants imitate facial expressions from a very early age (Meltzoff & Moore, 1977; Meltzoff, 1986). How good are infants at imitating speech sounds? No studies were found that address this issue for the production of particular kinds of speech sounds. Siegel, Cooper, Morgan, and Brenneise-Sarshad (1990) have studied if 9 to 12 month old infants spontaneously imitate either the average fundamental frequency or the fundamental frequency contour of their speaking partners. No tendency was found for infants to adjust vocal pitch, amplitude, or duration of either the father or the mother in a laboratory setting. However, infants are clearly able to control their fundamental frequency and have been observed using different registers when playing with two or more stuffed animals (Siegel et al., 1990).

8 Development of Speech Perception in Relation to Babbling

This paper does not review the large and growing literature on speech perception during the first two years of life. It is assumed that normal infants are able to perceive a superset of the phonemes present in the mother tongue, and that this capability develops prior to vocal imitation and spontaneous babbling of these sounds. See, for example, Kuhl, Williams, Lacerda, Stevens, and Lindblom (1992).

9 Conclusions

This paper briefly summarizes only a small part of the large literature on vocal babbling and speech and language acquisition in humans. There is also a large literature on infant

speech perception, blind infant speech perception and production, animal speech (sound) perception, and motor babbling. All of these subjects will certainly contribute to our understanding of early language acquisition.

However, the data presented here will provide a good starting point for the modeling of babbling in the context of speech production and perception. The main features of the data are the following: (1) The onset of babbling follows a long (relatively uniform in length) period of linguistic experience which may affect vowels, but does not initially affect babbling of consonants. (2) Feedback in the form of auditory or tactile speech is required for the onset of babbling. (3) Future cognitive skill does not seem to affect the time of onset or the content of babbling and late babbling. (4) The babbling repertoire is a small subset of the sounds of the target language. The infant's speech sound repertoire seems to increase rather slowly, only when adult words demand it. Similarly, the babbling repertoire does not depend significantly on the target language (except for some features of vowels). (5) Finally, there is continuity of development with mixing of stages, from the earliest sounds that the infant makes to the acquisition of more than 50 words. However, the onset of babbling seems to be a discrete event.

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