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PRECURSORS TO SPEECH IN INFANCY: THE PREDICTION OF SPEECH AND LANGUAGE DISORDERS

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During the canonical stage of infant babbling, infants produce well-formed syllables, often in reduplicated sequences such as "bababa." Although nearly all infants with normal hearing begin the canonical stage by 10 months of age, a few are delayed, and these infants may be of special interest. Recent studies indicate that late onset of canonical babbling may be a predictor of disorders. A simple screening procedure that focuses on canonical babbling was used to evaluate over 3400 infants at risk who were about 10 months of age. Among infants who showed late onset of canonical babbling, fewer than half had been previously diagnosed as having a significant medical problem that might have accounted for the delay. A follow-up study indicated that infants with delayed canonical babbling had smaller production vocabularies at 18, 24, and 30 months than did infants in the control group. The results suggest that late onset of canonical babbling, a factor that can be monitored effectively through an interview with a parent, can predict delay in the onset of speech production. © 1999 by Elsevier Science Inc.

Educational Objectives: The reader will become acquainted with four stages of vocal development in the first year of life; learn that during the *canonical stage* infants produce well-formed syllables that can function as words in languages; learn that the vast majority of infants enter the canonical stage by 10 months of age and that infants who are delayed in the onset are at extreme risk for hearing impairment and other speech and language-related disorders; find that parents almost always recognize the canonical stage when it occurs in infants; and become acquainted with evidence that an important screening for speech and language-related disorders can be conducted through a simple interview with parents of infants at 11 or 12 months of age.

KEY WORDS: Phonology, Infant vocalization, Babbling, Screening

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THE POSSIBILITY OF SCREENING BY EVALUATING INFANT VOCALIZATIONS THROUGH PARENT INTERVIEW

In the past two decades, the study of infant vocal development has yielded both deeper understanding regarding the nature of the emerging language capacity and new practical benefits in the assessment and treatment of emerging communication disorders. One of the important steps in this process has been the development of a stage model characterizing the sorts of speech-like sounds that are produced across the first year of life, and especially across the first half-year. The stages that have come to be recognized provide a framework against which to judge the potential anomalies of development that may occur in infants at risk for linguistic disorders.

The crowning stage of speech-like vocalization development is characterized by canonical babbling, the production of well-formed syllables, often in reduplicated sequences that are recognized by parents all over the world as [dɪdɪ], [baba], and so on. Because the onset of canonical babbling is easy to recognize, it has been proposed that it might provide the basis for a screening procedure capable of locating infants at high risk for speech and language disorders. This speculation motivated a body of research we and our colleagues have conducted at the University of Miami and the University of Maine. The goal of the work is to develop a screening system to identify infants at very high risk for emerging speech and language problems, and to do so in a manner that can be practically applied in a variety of settings, including hospitals, individual medical or nursing practices, daycare centers, and so on. The work has yielded encouraging results. It appears that a simple interview lasting no more than five minutes with parents of infants at the end of the first year of life may be able to provide the information necessary to locate a significant proportion of the infants with emerging speech and language disorders.

THE STAGES OF VOCAL DEVELOPMENT LEADING TO THE SPEECH CAPACITY

To understand why the proposed screening method works, it is important to take stock of the clear sense in which early vocalizations of infancy constitute *precursors* to speech. This is a critical point. If baby sounds were unrelated to speech, as was widely speculated at mid-century (see Carroll, 1960; Grégoire, 1948; Jakobson, 1941; Velten, 1943), then it might be expected that anomalies in the development of infant sounds would be irrelevant to speech. But research has proven the speculations of mid-century to have been groundless. In fact the sounds of the human infant develop systematically, and they can be shown to reflect a maturing speech capacity long before the infant says a single word.

The systematic nature of vocal development can be seen clearly in the con-

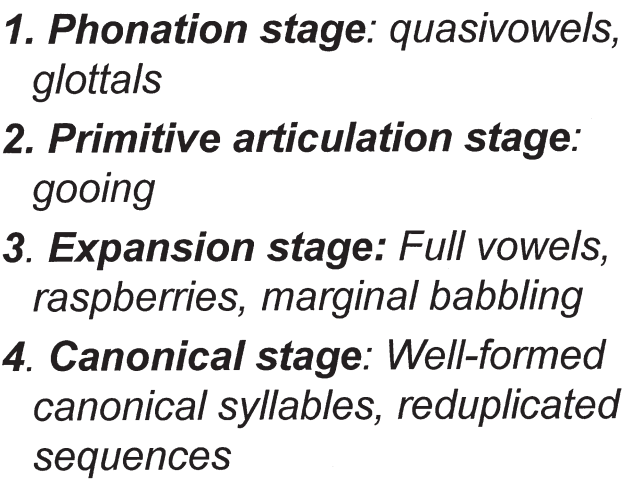

Figure 1. The stages of vocal development

text of a stage model that has been formulated to characterize the pattern of emerging speech abilities. At least four stages are recognized in what we have referred to as an international "consensus" (Oller, 1995). A number of longitudinal investigations of infant vocalizations (Elbers, 1982; Holmgren, Lindblom, Aurelius, Jalling, & Zetterstrom, 1986; Koopmans-van Beinum & van der Stelt, 1986; Oller, 1980; Stark, 1980; Zlatin, 1975) have been conducted since the 1970's and all of them have posited developmental patterns consistent with the summary provided in Figure 1.[1]

In order to understand the stage model, it is important to recognize first that vegetative sounds (coughing, sneezing, burping, and so on) and fixed vocal signals (crying, laughter, moaning, and so on) are treated separately from the critical sounds that are specific precursors to speech, the *protophones.* Vegetative sounds and fixed signals are present in many species, but protophones and speech are unique to humans. The stages, as formulated here, refer only to the protophones. In the past, many of the protophones were referred to as "babbling," but variations in usage of the term babbling have rendered the term sufficiently ambiguous that the coinage of a special word to designate the whole class of speech precursors seems justified.

[1]In many of the papers that have been published on this topic, the number of posited stages is greater than four. This apparent discrepancy across studies can be reconciled when we take note of the fact that a single stage in Figure 1 can be broken down into two or more substages. The various works can be seen to cohere in that they all show sequences that can be collapsed to the four stages. The same key features of development are recognized to occur in the same orders across all the studies. The different investigators appear to have observed the same phenomena and to have categorized the stages at differing levels of detail.

In the *phonation stage*[2], during the first 2 months of life, examples of the first of the protophones are produced by infants very frequently. These sounds are called quasivowels because they possess one of the required characteristics of vowels in mature languages. Quasivowels are produced with normal phonation, the kind of phonation that occurs in speech sounds, especially in vowels (Hollien, 1974). This kind of phonation differs notably from the kind of phonation that occurs in prototypical fixed vocal signals such as crying or laughing. Quasivowels differ from full vowel–like sounds (a later-occurring protophone type) in that the former are produced with the vocal tract at rest, rather than in any of the posturings of tongue, jaw, and lips that characterize the vowels of natural languages. In the *primitive articulation stage*, usually by 2–3 months of age, infants produce normal phonation and, at the same time, move the supraglottal vocal tract in producing protophones that are called gooing. To put it another way, during gooing, infants begin to articulate while vocalizing. Articulation is also a required feature of speech sounds. In the *expansion stage*, infants produce full vowel–like sounds, another protophone type in which the vocal tract is postured to exploit potential differences in the resonance properties of the vocal system, differences that create contrastivity among vowels. Further, during the expansion stage, infants articulate from a closed vocal tract (a consonant-like sound) to a postured full vowel while producing normal phonation. This sequence of actions yields a primitive protophone syllable that is called marginal babbling. There is only one key feature of well-formed syllables that is missing in marginal babbling: rapid transition from consonant-like element to vowel-like element. During the *canonical stage*, infants produce well-formed—or canonical—syllables, where the transition between consonant-like and vowel-like element occurs rapidly, just as it does in speech.

The four stages of protophone development culminate in canonical babbling; when it begins, parents all over the world recognize that their infants are nearly ready to start talking. In fact, parents tend immediately to try to shape their infants' vocalizations to word-like purposes. [Baba] thus may come to mean bottle, [dada] may come to mean daddy and so on, with the encouragement of parents (Papoušek, 1994). The tremendous resemblance between the syllables of canonical babbling and early words of infants (the so-called nursery terms) is, then, no accident. It has been well-proven by now that the phonetic characteristics of late babbling and early meaningful speech are extremely similar (Cruttenden, 1970; Murai, 1963; Nakazima, 1962; Oller, Wieman, Doyle, & Ross, 1975; Vanvik, 1971), even to the point that individual infant preferences for particular well-formed syllable types in babbling are reflected in a tendency for the same infants to prefer the same syllable types in early speech (Vihman, 1986). This undeniable similarity of canonical bab-

[2]The terminology for both stages and protophones is drawn mostly from Oller (1980) and Oller & Lynch (1992).

bling and speech proves beyond question that the two are deeply related. However, the evaluation of *precanonical* protophones also shows the emergence of a speech capacity, even though the sounds of the three earlier stages usually cannot be appropriately portrayed by phonetic transcription. The earlier protophones (quasivowels, gooing, marginal babbling, and so on) manifest the emerging capacity for speech by the fact that they incorporate infraphonological properties of speech (normal phonation, articulation, and consonant-vowel combination), and show the growth of the capacity across time by virtue of the fact that the properties are accumulated systematically (normal phonation alone in the *phonation stage*, normal phonation plus articulation in the *primitive articulation stage*, normal phonation plus articulation plus consonant-vowel combination in the *expansion stage*) (Oller & Lynch, 1992). Taken together, the evidence of similarity between canonical babbling and early speech and the systematic tendency for protophones to manifest a growing ability of the infant to command the characteristics of speech leave no doubt that protophones are indeed precursors to speech.

IMPORTANT ASPECTS OF CANONICAL BABBLING

Figure 2 summarizes important points about the nature of canonical babbling in the context of the goal of screening for disorders. Additionally, the figure

- *Well-formed syllables must be produced*
- *Each canonical syllable must have at least one full vowel-like element*
- *Each must have at least one consonant-like element*
- *Each must have a rapid formant transition between consonant and vowel*
- *Examples: [ba], [ata], [nunu], [di], [dada]*
- *Examples of noncanonical protophones: squealing, growling, raspberries, marginal babbling ...*

Figure 2. What is canonical babbling?

emphasizes the distinction between canonical babbling and a variety of precanonical protophones, which are related to speech, but more distantly than canonical babbling is. In general, we do not transcribe the precanonical protophones using the International Phonetic Alphabet, but instead categorize them broadly in terms that often conform to common parlance descriptions of the infant sounds (gooing, raspberries, and so on). In other cases, we provide new terms to refer to vocal precursors to speech (marginal babbling, quasivowels, and so on).

Like other motoric developments, such as crawling or walking, canonical babbling has a relatively narrow range of onset for normally developing infants. The typical age of onset is similar to that for crawling and sitting, with a mean around 6 months (Cobo-Lewis, Oller, Lynch, & Levine, 1996; Eilers, Oller, Levine, Basinger, Lynch, & Urbano, 1993; Koopmans-van Beinum & van der Stelt, 1986). It proves to be extremely important that normally developing infants rarely begin canonical babbling later than 10 months of age. This pattern of development has been verified in a wide variety of populations, summarized in Figure 3. Onset of canonical babbling occurs by 10 months of age in full-term normally developing infants (Koopmans-van Beinum & van der Stelt, 1986; Oller, 1980), in infants born into families of low socioeconomic status (Eilers et al., 1993), even very low socioeconomic status (Oller, Eilers, Basinger, Steffens, & Urbano, 1995), and in infants from differing home language backgrounds including multilingual ones (Oller & Eilers, 1982; Oller, Eilers, Urbano, & Cobo-Lewis, 1997). The pattern of timely onset for canonical babbling is very robust, then, in many infants often thought to be at risk for developmental disorders.

At the same time, there is dramatically clear evidence that some infants are delayed; in particular, infants with congenital profound deafness show delays in which the onset of canonical babbling almost always occurs *after* 10

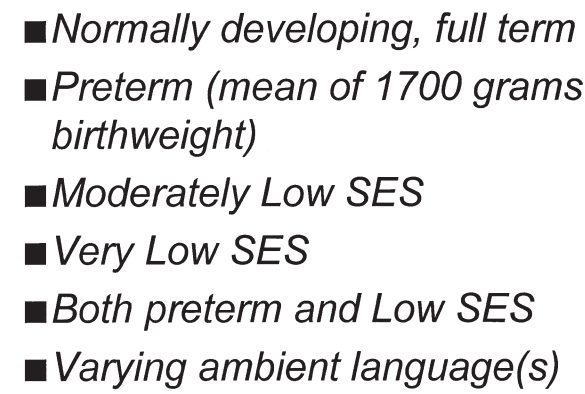

Figure 3. Populations that show stable CB onset by 10 months of age

months, and often the delays are of many months or even years (Eilers & Oller, 1994; Kent, Osberger, Netsell, & Hustedde, 1987; Koopmans-van Beinum, Clement, & van den Dikkenberg-Pot, 1998; Oller, Eilers, Bull, & Carney, 1985; Stoel-Gammon & Otomo, 1986; Vinter, 1987).[3]

THE SCREENING SPECULATION

Given that canonical babbling onset is very robust in a wide variety of populations, but is delayed severely and almost uniformly in a group known to show speech disorders (viz., infants with deafness), we have speculated that late onset of canonical babbling would perhaps be an excellent predictor of emerging speech and language disorders in general. Among the disorders that might be thus predicted are apraxia, dysarthria, specific phonological disorders, and perhaps more general language disorders. Even conditions such as autism—so difficult to diagnose early in life—might be predicted by late onset of canonical babbling. These speculations are based not only on deduction, but also on a pattern of results that has begun to emerge in the literature on vocal development. Four infants without hearing impairment have been reported with late onset canonical babbling (Koopmans-van Beinum et al., 1998; Stark, Ansel, & Bond, 1988; Stoel-Gammon, 1989), and of the four, two appeared on follow-up to have had a language-related impairment. One was a late talker (Stoel-Gammon, 1989) and the other showed early reading difficulties (Stark et al., 1988). Further, informal retrospective parent reports suggest that children with autism may sometimes show late onset of canonical babbling. Thus, both deductions and inductions suggest that screening for late onset canonical babbling among the population at large should net a relatively small number of infants (because late onset is rare), but that among those identified with late onset, a large proportion might prove to have emerging disorders, either because of hearing impairment or other conditions.

The Reliability of Parent Report about Canonical Babbling

The practical application of screening for late onset of canonical babbling requires that it be possible to identify infants who are late based on a quick and inexpensive procedure. Evidence to be considered in the present paper sug-

[3]So far in every published case where infants with very profound impairments have been followed longitudinally, they have been found to be delayed in canonical babbling onset. At the same time, recent evidence suggests that infants with moderate hearing losses sometimes show delays and sometimes do not (Oller & Eilers, 1998). Also, infants with some residual hearing—even though losses are in the severe or profound range—are not always delayed in the onset of canonical babbling (Koopmans-van Beinum et al., 1998; Oller & Eilers, 1998).

gests that such a procedure can be based on an interview with parents. The reliability of parent report on canonical babbling appears to be remarkably high. A series of studies in our laboratories have suggested that parents of 11- and 12-month-old infants provide descriptions of their infants' vocalizations from which laboratory assistants can easily (and almost always correctly) assign the infants to canonical or precanonical categories (Oller, Basinger, & Eilers, 1996). The correctness of the parental descriptions is verified in these studies with subsequent laboratory evaluations of infants by separate staff. The trick to making the interview method work is to ask open-ended questions (such as, What kind of sounds does your baby make?) rather than directed questions (Does your baby say things like [baba] or [dada]?). In the context of open-ended questions, parents generate descriptions that are based on observation. In the context of directed questions, parents sometimes answer in a way they seem to presume will please the questioner, in a pattern contaminated by what social psychologists call *acquiescence response bias* (Lehman, Krosnick, West, & Li, 1992).

It stands to reason that parents should be skilled at recognizing canonical babbling, because well-formed syllables are the building blocks of speech. If a parent could not recognize such sounds (indeed, if any grownup could not recognize such sounds), then that individual would not be able to tell the difference between speech and other kinds of less well-formed vocalizations. Mature speakers of natural languages in fact recognize even subtle foreign accents, and easily notice aberrations of speech in individuals with such conditions as motor aphasia, dysarthria, or deafness. The distinction between canonical babbling and precanonical vocalization is no less clear than that between well-formed and disordered speech.

Further, if parents did not *notice* their infants' early canonical syllables, they would not be in a position to make adjustments in how they talk to infants, adjustments in which they appear to shape infant syllables to the requirements of speech communication. Observational research suggests that parents of infants in the first year of life make unconscious—but very effective—adjustments to developmental changes in infant vocal patterns, especially at the beginning of the canonical stage (Papoušek, 1994). Since parents do appear to be capable of providing reliable descriptions of their infants' status, it should be possible to develop a practical screening procedure based upon a simple interview method.

The Telephone Screening Project

For several years, under funding from National Institute on Deafness and Other Communication Disorders, we conducted a program of screening based on telephone interviews and follow-up with selected infants. The goals of the work have included establishing a reliable estimate of the proportion of in-

fants who show late onset of canonical babbling, determining through follow-up studies the proportion of late canonical babblers who show significant indications of speech or language disorders, and providing further evidence of the applicability of a screening procedure based on interviews with parents. Because the disorders we sought to identify are rare, the numbers of infants to be screened were necessarily large. Partly due to the accessibility of populations at the University of Miami's Medical School, where the screening was conducted, and partly in order to maximize the yield in infants with potential disorders, we chose to screen a largely high risk population.

There have been several prior reports from our laboratories on this study, based on analyses at various points in the acquisition of data (Eilers, Neal, & Oller, 1996; Eilers, Oller, & Cobo-Lewis, 1997; Oller et al., 1996; Oller & Eilers, 1998; Oller, Eilers, Neal, & Cobo-Lewis, 1998). The data to be reported here represent the final corpus; no further subjects are being screened, and the follow-up has been discontinued. Methodology for the study is described in detail in (Oller et al., 1998), and so will be treated only in brief form here.

In all, 3469 telephone interviews with parents of infants from a relatively high risk population were conducted. The great majority of the infants were at risk for developmental disabilities due to a variety of factors, including low birthweight and exposure to various illnesses or drugs, as well as low socioeconomic status. Infants who had been determined to have hearing impairment through newborn screening were not included in the population for this particular study (another effort was mounted to follow those infants).

Interviewers called parents when their infants were 10–12 months old. In the context of a more general interview about the infants' health and welfare, staff pursued certain questions specifically designed to elicit parental observations about their infants' vocal capabilities. The interviewers first asked open-ended questions (Tell me what kinds of sounds the baby makes.). They then asked directed questions (Does the baby say things like [aba], [da], [baba], [dada], [mama], or . . .). After each set of questions, interviewers registered infants as canonical or noncanonical. Interviewers attempted to schedule each infant designated as noncanonical on either part of the interview for a laboratory confirmation.[4] Additional controls (infants canonical on both interview sections) were also brought into the laboratory. During each laboratory session—which occurred as soon as possible, but often several weeks after the interview, staff evaluated each infant and rendered a judgment of canonical or noncanonical based on the infant's behavior during the laboratory session. Infants in both the late canonical babbler group and the much larger control

[4]The open-ended questions, in general, provided the information utilized in the present report. A prior publication provides a breakdown of outcomes for the two types of questions (Oller et al., 1998).

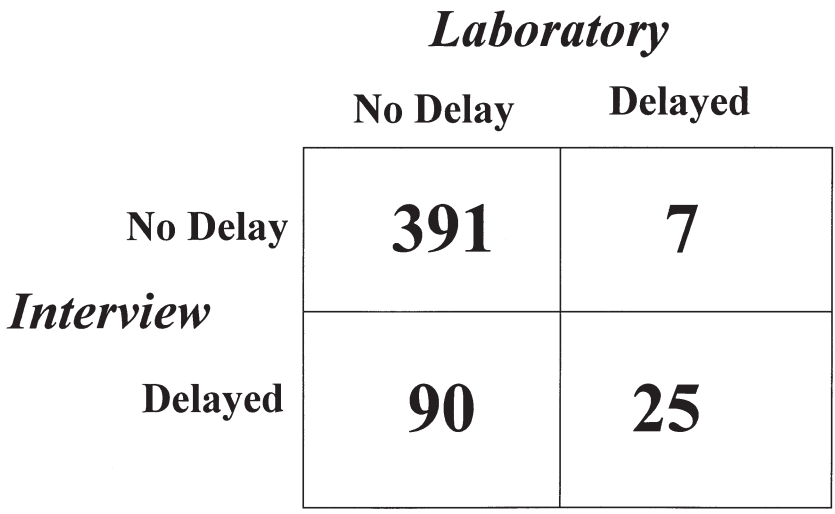

Figure 4. Summarial data on concordance: tested values

group were often brought in for several sessions (if parental agreement and cooperation could be obtained) in order to provide secure information about the onset of canonical babbling. Further, infants in the late canonical babbler group, along with a similar number of control infants, were brought into the laboratory for a follow-up in which additional evaluations were conducted—through 30 months of age when possible—to assess general development and especially vocabulary acquisition.

Numbers of Infants Showing Late Onset of Canonical Babbling

Figure 4 provides the final data on all of the infants screened both by telephone and in the laboratory. In this high risk population, it was often not possible to complete laboratory evaluations, either because parents refused to schedule an appointment or failed to show up even if they did, even though they were being paid to make the visit. It was possible to evaluate only about half the infants deemed to be late onset canonical babblers in the laboratory.

First, note that 25 infants were found to be delayed according to both laboratory and telephone (either open-ended or directed) results. An additional 7 infants were identified as late canonical babblers in the laboratory, even though they had been brought in as controls—infants whose parental descriptions had suggested that they were already canonical at the time of the initial

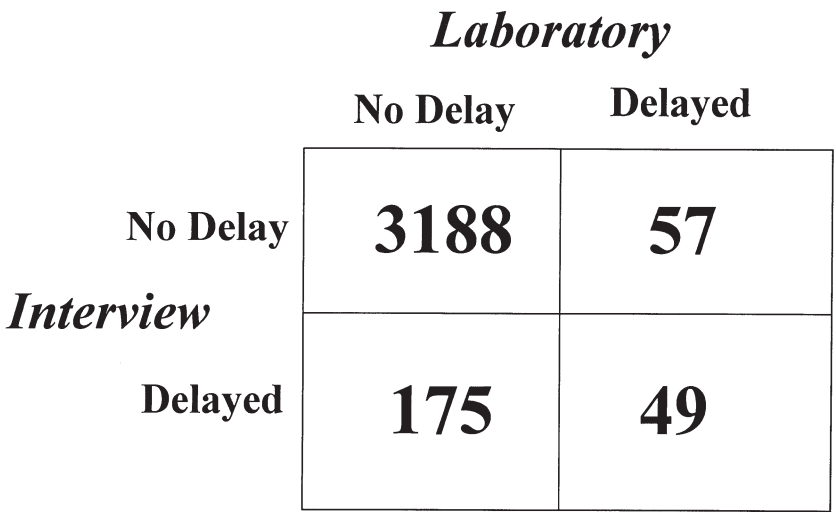

Figure 5. Summarial data on concordance: projected values

telephone contact. Thus a total of 32 infants were actually found to be late canonical babblers.[5]

While the data in Figure 4 represent the infants that actually came to the laboratory in addition to being categorized based on the telephone sample, the numbers provided do not by themselves specify an estimate of the prevalence of late onset canonical babbling. In order to estimate the number of infants who could be expected to have been delayed (given that only about half of the total were successfully scheduled for laboratory assessment, and that fewer than 12% of the infants sampled were evaluated in the laboratory as control subjects), it is necessary to project the numbers of infants that likely would have been verified as late canonical babblers based on the pattern of results in infants who were actually seen in the laboratory. The projected values are re-

[5]The data reported here are based on a somewhat more rigid criterion for lateness than in a prior publication (Oller et al., 1998). The prior report was based on an analysis conducted when a little less than half the total screening sample had been evaluated. In the present compilation of the data, we have insisted that each infant designated as late in the laboratory show at least one official noncanonical sample in the laboratory after reaching 11 months of age, corrected for gestation, and no intervening laboratory session categorized as canonical. The different criterion in the prior compilation of data (where infants were categorized as late if their first laboratory session was noncanonical, even if the session occurred beyond 11 months corrected age) yielded a slightly higher estimate of the rate of occurrence of late onset canonical babbling, 3.3%, compared with 3.1% in the present work. The shift in criterion helps to clarify the proportion of infants with late onset of canonical babbling (because it provides a firm age value for the judgment), but it also produces an illusory reduction in the apparent concordance between parent-based and laboratory-based judgments.

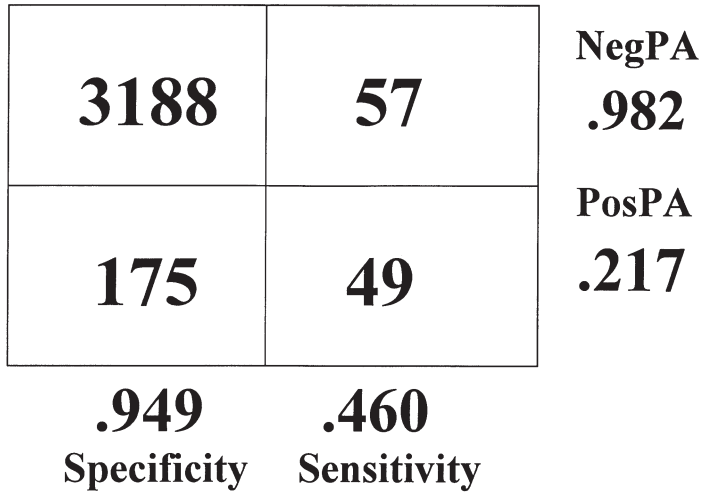

Figure 6. Summarial data on concordance: clinical biostatistics

ported in Figure 5, based on proportional extrapolation from the values in Figure 4. In Figure 5 we see that 49 infants are projected to have had late onset of canonical babbling, according to both assessments, and that an additional 57 are projected to have had late onset canonical babbling in the laboratory only. This total of 106 represents 3.1% of the 3469 infants screened, and provides the best current estimate of the proportion of infants with late onset canonical babbling in this high risk population. It should be emphasized that the estimate presumably provides only an upper limit on the proportion of infants that would be expected to show late onset of canonical babbling in the population at large.

Figure 6 provides values for sensitivity and specificity as well as positive and negative predictive accuracy based on the proportionally projected data. The sensitivity value suggests that the screening procedure could locate nearly half the infants (at this level of developmental risk) with late onset canonical babbling. The specificity suggests that nearly 95% of infants at this age with normal onset of canonical babbling would be correctly excluded (i.e., judged canonical) by the interview-based screening. The negative predictive accuracy indicates that over 98% of infants designated as canonical in the interview would truly be canonical. The positive predictive accuracy suggests that about one-fifth of infants designated as late canonical babblers, based on the parental interview, would be likely to show late babbling in the laboratory as well.

It is important to emphasize that the data in Figure 6 provide conservative estimates of the potential utility of the screening procedure. A number of factors in the way the present study was conducted offer only conservative esti-

mates of the validity of categorization based on parental report of canonical babbling. For example, the average lag between telephone interview and laboratory session was more than 3 weeks. Consequently, many infants may have changed from noncanonical to canonical during the intervening period, resulting in a false appearance of discordance between the data based on the telephone interview and the laboratory session. Further, the fact that many infants failed to produce canonical babbling in the laboratory (in a single session) does not provide reliable evidence that such infants were not canonical. Infants were often silent during the scheduled 20-minute periods of laboratory sampling, in spite of efforts to elicit vocalization. In some cases, control infants failed to show canonical babbling in the laboratory session even though parents insisted that the infants did indeed commonly produce well-formed syllables. Subsequent sampling with the same infants often confirmed the parents' observations. Since control infants were not seen as many times in the laboratory as follow-up infants (those designated as late babblers in the laboratory), it is likely that the number of false canonical judgments (canonical at telephone interview, but noncanonical in the laboratory) was inflated. The real situation, by which we mean the veridical clinical biostatistics on how accurately parents describe their infants' babbling, can be assumed to be much more favorable to the development of a practical screening procedure than those reported here.

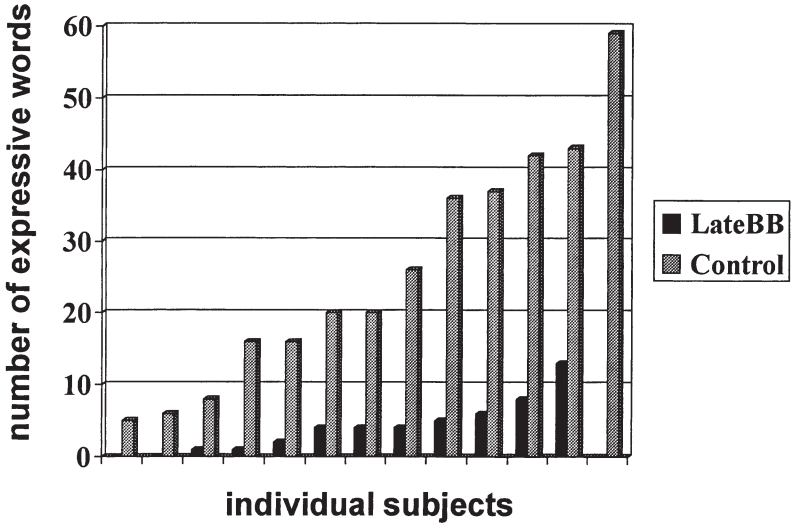

Figure 7. MCDI results on number of expressive words: 18 months

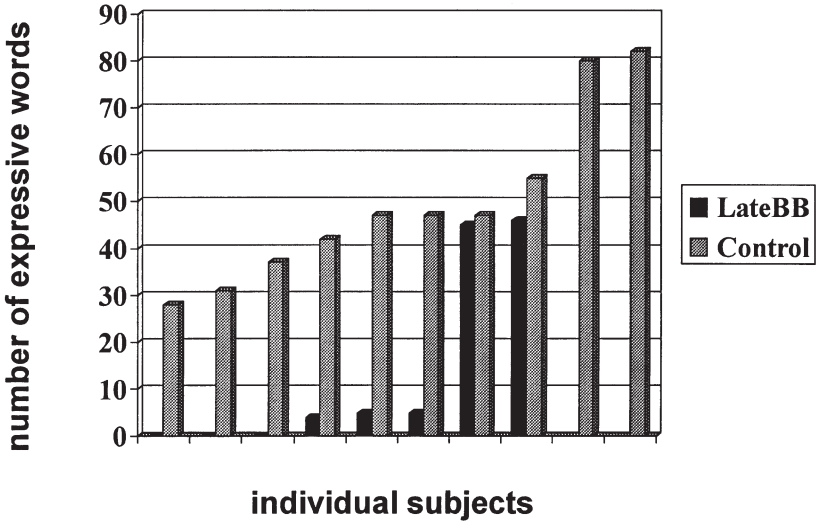

Figure 8. MCDI results on number of expressive words: 24 months

Disorders and Delays in the Follow-up Sample

Fewer than half the infants with late onset of canonical babbling showed frank disorders that would have been diagnosed independent of their vocalization assessments. The frank disorders included cerebral palsy, laryngeal paralysis,

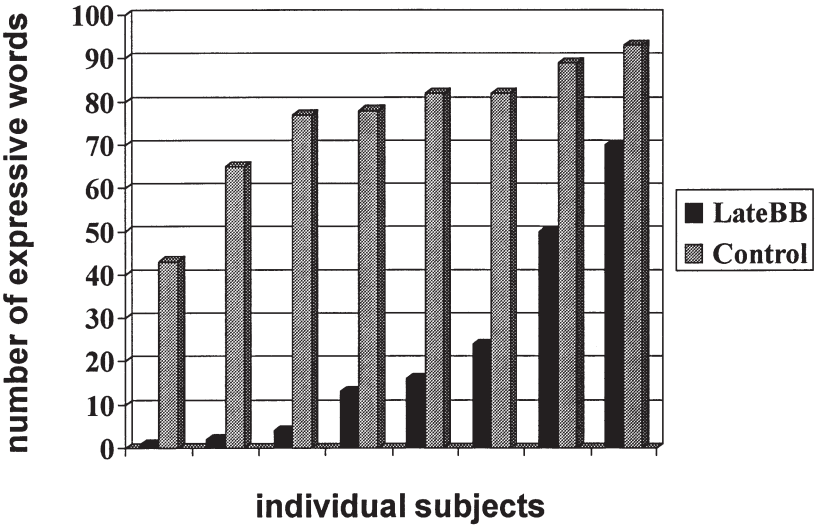

Figure 9. MCDI results on number of expressive words: 30 months

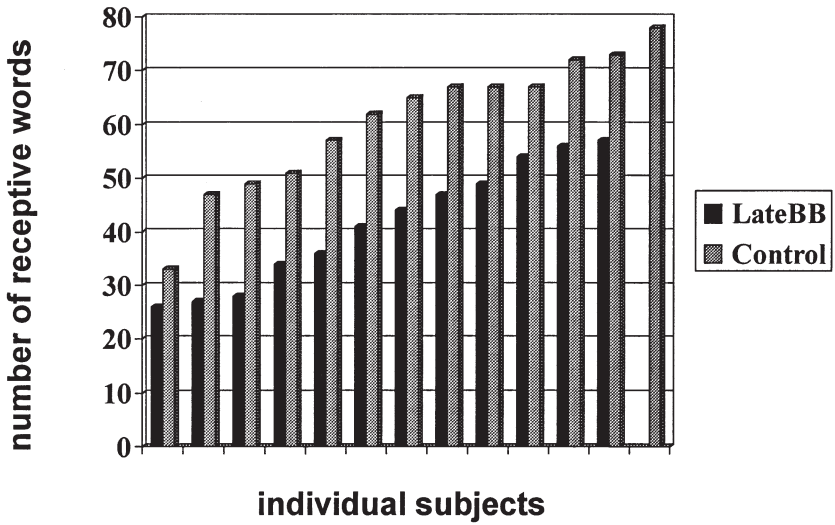

Figure 10. MCDI results on number of receptive words: 18 months

epilepsy and others. At least 3 infants were diagnosed as having important disorders (neurological) *after* referral due to late canonical babbling onset (see Oller et al., 1998 for tabulations of disorders).

A follow-up study was conducted to assess vocabulary development in the infants with late onset of canonical babbling. A control sample, drawn from the same high risk population, was also followed. The control infants, of course, did not show late onset of canonical babbling, but greatly resembled the late babblers in risk factors and medical histories. The study followed as many of the late babblers as possible, with one constraint. Infants with severe medical problems were excluded. The goal of the follow-up was to help assess the screening procedure in terms of its value in predicting speech and language disorders that could not be predicted by more obvious means. Thus, for example, infants with obvious cerebral palsy were not followed up because they would have been designated as at risk for speech and language disorders on grounds unrelated to babbling.

The results for expressive vocabulary development on the MacArthur Communicative Development Inventory (Fenson, Dale, Reznick, Thal, Bates, Hartung, Pethcik, & Reilly, 1991) at 18 months of age in the two groups differed dramatically. Figure 7 shows that 12 late canonical babblers trailed 13 control infants as a group and that only 2 infants in the late canonical babbling group had vocabulary within the range shown by the control infants. Notice that the level of vocabulary development was low in both groups, as expected given their risk status.

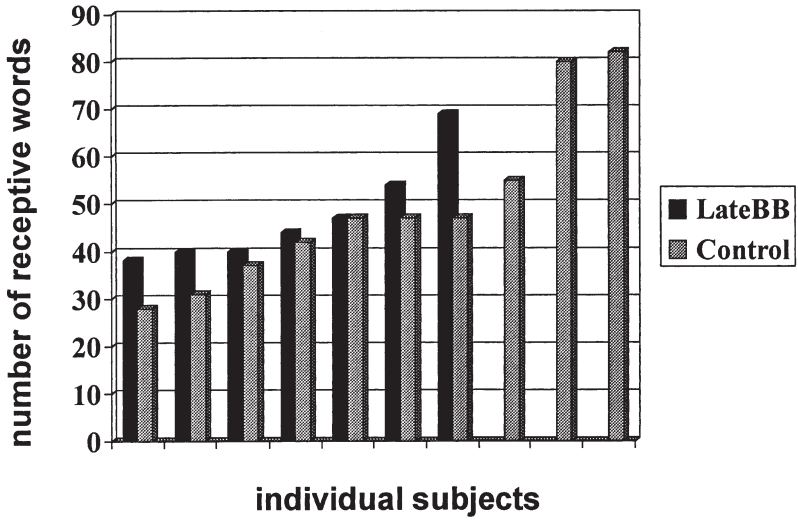

Figure 11. MCDI results on number of receptive words: 24 months

By 24 months of age (Figure 8) subject attrition had reduced the sample to 8 late canonical babblers and 10 controls, but the pattern of difference persisted. The same 2 infants with late canonical babbling were within the range of the control group, but the remaining late canonical babblers were substantially delayed. The pattern continued at 30 months (Figure 9).

The results were not the same for receptive vocabulary. At 18 months the groups differed, but not dramatically, and there was substantial overlap between the groups (Figure 10). At 24 months (the last age at which the receptive vocabulary evaluation could be appropriately applied), the groups showed no important differences (Figure 11).

CONCLUSIONS

The research suggests that assessment of canonical babbling through a procedure no more complicated than a telephone interview lasting a few minutes can be extremely helpful in identifying infants who are at very high risk for speech and language disorders. In the present work, fewer than half the infants who began canonical babbling after 10 months of age had serious, routinely diagnosed medical problems. But most had been given no significant diagnosis, and among those who had not, some[6] were given a significant medical di-

[6]We can estimate that, in addition to the infants with obvious, already diagnosed disorders, another 10% of infants who are determined to have late onset of canonical babbling may be given a significant medical diagnosis after referral due to late onset of canonical babbling.

agnosis *after* they were referred for further evaluation based on their delayed vocal development. Furthermore, among those late canonical babblers with either no reported medical problems or only minor ones, the great majority showed significant delays in expressive vocabulary development through at least 30 months of age. Receptive vocabulary did not differ dramatically between the late canonical babbling and control groups.

The pattern of results suggests that late onset of canonical babbling may be related to rather specific disorders in phonological capabilities. The child who shows late canonical babbling may also show a delayed ability to speak, but not a delayed ability in understanding individual words at 2 years of age. It remains possible that the conditions that produce late babbling and slow acquisition of expressive words in the second and third years of life may set off a cascade, negatively affecting a variety of additional linguistic capabilities down the road. The root difficulty in infants with late onset of canonical babbling could be one of limited phonological production capabilities, but the difficulty could also pertain to retrieval of phonological representations. Either way, the effects could generalize to other aspects of communication due to failures in acquisition of retrievable representations and due to consequent inadequacies of verbal interaction. Language and literacy could both be affected in important ways by the core problem (whatever it may be) that causes late canonical babbling.

The present results strongly suggest that late onset of canonical babbling could become a critically important aspect of a screening battery for developmental disabilities at the end of the first year of life. The potential success of the approach is supported by data indicating that an inexpensive method of interview that could be conducted in a variety of settings, even on the telephone, can yield numerous identifications of infants at extreme risk for speech and language disorders. It should be recalled that the present study excluded infants with hearing impairment explicitly (those infants are being evaluated in a separate work). Still, the practical screening approach that the results support would be likely to net both infants at high risk for specific speech and language disorders and infants that have severe or profound hearing impairments. In fact, screening for late onset of canonical babbling at the end of the first year of life may be the most cost-effective method available to identify infants with severe or profound hearing impairment, and could provide an important addition to audiological screening conducted in newborn nurseries (Bess & Hall, 1992; Weber, 1988).

The results on the efficiency of the envisioned method of screening may substantially underestimate the potential of the approach. The fact that the "gold standard" laboratory evaluation was usually conducted more than 3 weeks after the telephone interview may have produced many misleading cases of apparent discordance. Other research suggests that the estimated clinical biostatistics improve significantly with short intervals between interview and laboratory evaluation (Oller et al., 1996). Further, failure of infants to pro-

duce canonical babbling in the laboratory was often attributable merely to the fact that sessions were short; infants sometimes fell asleep or simply maintained silence. Sometimes, of course, the telephone interview judgments of canonical were genuinely mistaken, and in some of those cases it appeared that the interviewees had not been primary caretakers of the infants and may have speculated about vocalizations that they thought the infants might be able to produce, even though they did not have sufficient information to justify the speculations.[7]

A number of changes in procedure would be likely to increase the efficiency of the envisioned screening evaluation. For example, it seems highly likely that interviews with the population at large would yield somewhat more reliable results than interviews conducted only with parents of infants at risk. The population studied in the present work was largely poor and often in distress; often it was difficult even to inspire response to telephone inquiries from families trying to make ends meet in difficult circumstances.

In general, face-to-face interviews with parents, especially in the presence of infants, might dramatically enhance sensitivity, specificity, and predictive accuracy of the procedure. Such an approach might be especially effective in the context of an inexpensive general health care model where parents and infants at the end of the first year of life are given a general health care evaluation by a nurse or medical paraprofessional. Since such an evaluation might last a half hour or more, there could be substantial opportunity to observe the infant and potentially to verify parental report about canonical babbling. Even in more traditional pediatric evaluations, of course, screening for late onset of canonical babbling could be useful.

The potential importance of identifying infants with significant speech and language-related problems early in life seems clear. Early intervention appears to be the key to limiting the ill-effects of developmental disabilities (Musselman, Lindsay, & Wilson, 1988; Ramey & Campbell, 1984; Resnick, Armstrong, & Carter, 1988; Schweinhart, Weikart, & Larner, 1986). Identifying infants with late onset of canonical babbling may provide an important new element in an effective screening battery that could facilitate prevention or amelioration of important communicative disabilities.

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[7]The telephone interviewers always asked to speak with a primary caretaker, but in some cases later contact with the families in laboratory sessions suggested that the telephone interviewee had not in fact qualified as a primary caretaker.

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CONTINUING EDUCATION

Precursors to Speech in Infancy: The Prediction of Speech and Language Disorders

QUESTIONS

1. The study of infant vocal development has revealed that
   a. Infant babbling is not related to speech
   b. Infants are all so different that it is not possible to recognize stages of vocal development
   c. Protophones are precursors to speech
   d. Protophones are the same as vegetative sounds in terms of significance
   e. None of the above

2. The fourth or ‘canonical stage’ stage of vocal development can be recognized by
   a. The production of marginal babbling
   b. The use of quasivowels and laughter
   c. The production of wailing sounds and social use of crying
   d. The production of well-formed syllables
   e. None of the above

3. Parents who are asked to describe the vocalizations of their 11 or 12 month old infants
   a. Usually say things that cannot be interpreted by interviewers familiar with the four vocal development stages
   b. Usually give clear evidence about whether their infants are in the canonical stage to interviewers familiar with the four vocal development stages
   c. Are only good at describing words and other vocalizations that have meaning
   d. usually do not remember much about their infants’ sounds
   e. None of the above

4. Infants who prove to be delayed in the onset of canonical babbling
   a. Are at extreme risk for hearing impairment or other speech and language-related disorders
   b. May be expected to catch up with their peers within the next month
   c. Are also delayed in the onset of raspberries and squealing sounds
   d. Never learn words within the second year of life
   e. All of the above

5. A screening procedure based on an interview with parents of infants with 11 or 12 month old infants could
   a. Determine whether or not infants have had otitis media in recent months
   b. Help to identify certain infants at very high risk for important disorders, but the cost of conducting the screening would be high
   c. Help to identify certain infants at very high risk for important disorders, and the cost of conducting the screening would be low
   d. Help locate particularly insightful caretakers of infants
   e. None of the above