proline-rich regions have been identified in several other mammalian transcription factors including AP-2 (*24*) and c-Jun/AP-1 (*25*). Future studies will likely define the domains of p65 required for DNA binding, dimerization, association with IκB, and transactivation.

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Babbling in the Manual Mode: Evidence for the Ontogeny of Language

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Infant vocal babbling has been assumed to be a speech-based phenomenon that reflects the maturation of the articulatory apparatus responsible for spoken language production. Manual babbling has now been reported to occur in deaf children exposed to signed languages from birth. The similarities between manual and vocal babbling suggest that babbling is a product of an amodal, brain-based language capacity under maturational control, in which phonetic and syllabic units are produced by the infant as a first step toward building a mature linguistic system. Contrary to prevailing accounts of the neurological basis of babbling in language ontogeny, the speech modality is not critical in babbling. Rather, babbling is tied to the abstract linguistic structure of language and to an expressive capacity capable of processing different types of signals (signed or spoken).

A KEY FEATURE OF HUMAN DEVELOPment is the regular onset of vocal babbling well before infants are able to utter recognizable words (*1*). Vocal babbling is widely recognized as being continuous with later language acquisition (*2*). The prevailing view is that the structure of vocal babbling is determined by development of the anatomy of the vocal tract and the neural mechanisms subserving the motor control of speech production (*3, 4*). In brain-based theories of language representation, it is argued that the human language capacity has a unique link to innate mechanisms for producing speech (*5*); it has also been argued that human language has been shaped by properties of speech (*6*).

Although there is general agreement that humans possess some innately specified knowledge about language (7), the maturation of the human language capacity may not be uniquely tied to the maturation of speech-specific production mechanisms. Naturally evolved human signed languages exist that are organized identically to spoken languages (for example, phonology, morphology, syntax, and semantics) (*8*). If babbling is due to the maturation of a language capacity and the articulatory mechanisms responsible for speech production, then it should be specific to speech. However, if babbling is due to the maturation of a brain-based language capacity and an expressive capacity capable of processing different types of signals, then it should occur in spoken and signed language modalities.

Hearing infants between 7 and 10 months of age begin to produce a type of vocalization described as reduplicated or syllabic babbling, for example, "dadadada" or "babababa" (*9*). Syllabic vocal babbling is characterized by (i) use of a reduced subset of possible sounds (phonetic units) found in spoken languages (*10*), (ii) syllabic organization (well-formed consonant-vowel clusters) (*11*), and (iii) use without apparent meaning or reference (*12*). Other properties include reduplication, well-defined age of onset, characteristic stages (*12*), and continuity of phonetic form and syllabic type within an individual child's babbling and first words (*2*).

In this study, experimental and naturalistic data were collected from five infants, each videotaped at three ages (approximately 10, 12, and 14 months). Two subjects were profoundly deaf infants of deaf parents (D1 and D2), acquiring American Sign Language (ASL) as a first language. Three control subjects were hearing infants of hearing parents (H1, H2, H3), acquiring spoken language with no exposure to a signed language (*13, 14*).

In studies of vocal babbling, investigators typically transcribe all acoustic forms or sounds produced over a period of time (*15*) and analyze all acoustic forms that are not words to see if they have any systematic organization. If systematic organization is found, the investigator determines whether the organization has phonetic and syllabic features common to spoken languages (*2*).

We analyzed the deaf and hearing infants' manual activities in an identical manner. First, all of the infants' manual activities were transcribed and entered into a comput-

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er database (*16*) with a transcription system that we had devised and tested (*17*). In this system, the precise physical form of the child's every manual activity is coded with diacritics that represent internal features of the hand or hands, such as its handshape and location in space. The precise manner of use is also coded for each manual activity, including whether the form was used with or without objects in hand, used referentially, used communicatively, had conventional meaning, or was a standard sign in ASL (a sign has identical linguistic properties to a word in spoken languages) (*18*). Second, we further analyzed all manual activities that were not ASL signs and were not pointing to objects to determine whether they had any systematic organization. If so, we analyzed these activities to determine whether they had unique organizational properties or whether they shared phonetic and syllabic organization common to signed languages (*19, 20*). Attribution of manual babbling was applied only to forms that fulfilled the same criteria as vocal babbling. This transcription system permitted direct comparisons of the manual activities of the deaf and hearing infants. The reliability of rating for two independent coders ranged from 82 to 95% (*21*).

The results yielded two types of manual activity: syllabic manual babbling and gestures (for example, raising arms to be picked up and holding a cup to lips as if to drink). Both types were observed in deaf and hearing infants. The manual activities identified as syllabic manual babbling (i) were produced with a reduced subset of combinatorial units that were members of the phonetic inventory of signed languages (*20*), (ii)

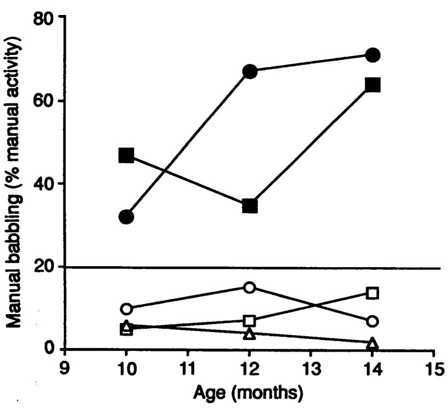

Fig. 1. Manual babbling as a percent of manual activity [manual babbling/(manual babbling + gesture)]. Open symbols represent the hearing children and closed symbols represent the deaf children (□, H1; △, H2; ○, H3; ●, D1; and ■, D2). The required syllabic ratio is 20% (line) syllabic to total vocal utterances for children to be classed in the syllabic vocal babbling stage of language acquisition (7). The deaf children met and surpassed this ratio in their manual babbling, but the hearing children did not.

Table 1. Tokens of gestures and manual babbling produced by each child over the three taping sessions.

Child	Gesture	Manual babbling
	Hearing	
H1	98	10
H2	195	8
H3	121	14
	Deaf	
D1	101	80
D2	122	111

demonstrated syllabic organization seen only in signed languages, and (iii) were produced without meaning or reference. By contrast, gestures were not constructed from a restricted set of combinatorial units, had no principled internal organization, and were used referentially (*22*).

Hearing and deaf infants produced similar types and quantities of gestures during the three sessions. However, they differed in their production of manual babbling (Table 1). Manual babbling accounted for 32 to 71% of manual activity in deaf infants and a mere 4 to 15% of the manual activity of hearing infants (Fig. 1).

In manual babbling, the deaf infants used a reduced subset of the phonetic units found in ASL (*23*): 32% (13/40) of the handshapes (*20*) that make up the phonetic inventory of adult ASL (Fig. 2). Of these 13 handshapes, 6 were used 75% of the time: 5, 52, A, A2, O, and G (*24*). The deaf infants produced 54% (13/24) of ASL's movements (*20*); the three most frequently used were the closing of a handshape, movement toward the body, and an up-and-down movement. Most of the deaf children's manual babbling (98%, 188/191) was produced within a restricted space in front of the body. In addition, each infant had an individual preference regarding the location (*20*): most of D1's manual babbling was produced in the space in front of the mid-torso (neutral space), whereas the majority of D2's manual babbling involved contact with the head, ears, and face region. Similarly, hearing infants demonstrate clear individual preferences in the phonetic content of their vocal babbling (*25*).

The manual babbling of the deaf infants contained four syllable types (*20*), a subset of which were used more frequently (Fig. 3). D1 predominantly produced syllables involving secondary movement in the form of handshape change (69%). D2 predominantly produced syllables involving path movement (69%).

The deaf infants' manual babbling demonstrated four other properties observed in hearing children's vocal babbling. First,

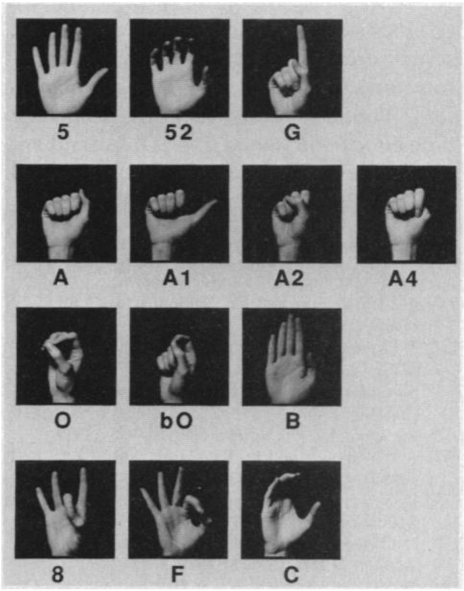

Fig. 2. The 13 handshape primes produced by the deaf children in their manual babbling. The handshape A4 does not occur in adult ASL; it is a possible but nonexistent phoneme.

reduplication occurred in 47% of the tokens of sign babbling produced by the deaf infants (*26*). Second, by age 10 months, the deaf infants were well into the syllabic manual babbling stage, which occurred at the same time as in hearing infants (ages 7 to 10 months). Third, the deaf infants progressed through stages of manual babbling similar to the stages of vocal babbling observed in hearing infants, and on a similar time course. Hearing children produce vocal jargon babbling (meaningless babbling sequences that sound like sentences; onset 12 to 14 months) (*12*); similarly, the deaf infants produced manual jargon babbling (onset 12 to 14 months). They produced phonologically possible, but nonexisting, forms in the ASL lexicon; the forms maintained the rhythm and duration of rudimentary ASL sentences and were similar to hearing infants' use of stress and intonation in vocal jargon babbling (*12*). Fourth, there was a continuity between the phonetic and syllabic forms used in the deaf infants' manual babbling and their first signs. For each infant, the most frequent phonetic units in his or her manual babbling were also the most frequent in his or her first signs: the 5 handshape was most frequent for both D1 [manual babbling (m.b.) = 27%, signs (s.) = 43%] and D2 (m.b. = 29%, s. = 54%); the most frequent movement type produced by D1 was the closing of a handshape (m.b. = 55%, s. = 36%), and D2's most frequent movement type was movement toward the signer (m.b. = 29%, s. = 40%); D1 continued to produce signs in neutral space (m.b. = 82%, s. = 59%), and D2 maintained a preference for locations in the head and face area (m.b. = 51%, s. = 53%). As for syllables, D1 continued to prefer handshape-change syllables (m.b. = 69%, s. = 44%), and D2 continued to prefer location-change syllables (m.b. = 69%, s. = 58%). Thus, like hearing infants (*2*), deaf infants produce their first signs from the pool of phonetic and syllabic types rehearsed in their babbling. Further, the deaf infants' first signs and the hearing infants' first words occurred at similar ages: D1 (10 months, 10 days), D2 (11 months, 28 days), H1 (11 months, 6 days), H2 (12 months, 11 days), H3 (12 months, 14 days).

The hearing infants in this study produced few instances of manual babbling (Table 1). They used an even smaller subset of phonetic units than did deaf infants, displaying only three handshapes (F, O, bO; 80%, 28/35) (*27*), one movement (thumb to digit contact plus repeated rub; 84%, 27/32) and one location (neutral space; 100%, 32/32). Further, they used primarily one syllable type (handshape change; 88%, 28/32). This is similar to deaf infants' limited production of syllabic vocal babbling, which also shows little variation in form and a very reduced set of consonants and vowels (*11, 28*).

Our data do not support the notion that babbling is determined by motor developments of the articulatory mechanisms subserving speech production (*4*). Instead, babbling is an expression of an amodal, brain-based language capacity that is linked to an expressive capacity capable of processing speech and sign. Despite radical differences

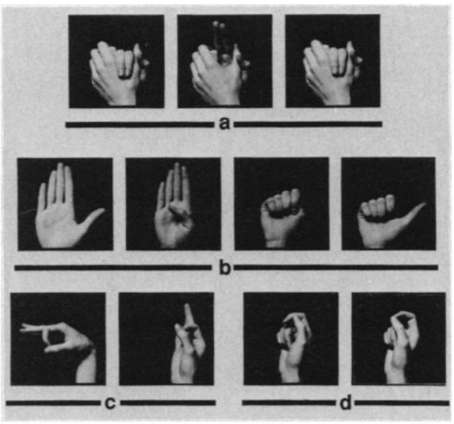

Fig. 3. Examples of syllable types in manual babbling. In real time these are continuous forms; in order to demonstrate the handshapes that occur, the forms have been presented as sequences of static pictures. All forms were reduplicated; only the basic unit is presented here. (**a**) A two-handed handshape-change syllable. (**b**) A unimanual, bisyllabic, handshape-change production involving four distinct handshapes. (**c**) An orientation-change syllable produced by a flexing of the wrist. (**d**) A handshape-change syllable typically produced by the hearing children, which is much less complex than that shown in example (b).

between the motoric mechanisms that subserve signed and spoken languages, deaf and hearing infants produce identical babbling units. Both manual and vocal babbling contain units and combinations of units that are organized in accordance with the phonetic and syllabic properties of human language. Thus, the form and organization of babbling is tied to the abstract linguistic structure of language.

Infants appear to be innately predisposed to discover the particular patterned input of phonetic and syllabic units (*29, 30*), that is, particular patterns in the input signal that correspond to the temporal and hierarchical grouping and rhythmical characteristics in natural language phonology. We suggest that this predisposition is a property of an amodal language capacity. Patterned input in either the signed or spoken modalities with phonetic and syllabic organization can serve as the vehicle for language production and reception, thereby triggering a babbling stage (*31*). Babbling is thus the mechanism by which infants discover the map between the structure of language and the means for producing this structure. The production of babbling units helps infants to identify the finite inventory of basic units, and the permissible combination of these units, from which language will be constructed (*29*). By attending to particular patterned input, infants can begin to acquire the basic forms of language well before they have mastered adult knowledge of language structure and meaning.

Similarities in the time course, structure, and use of manual and vocal babbling suggest that there is a unitary language capacity that underlies human signed and spoken language acquisition. Like other systems identified in evolutionary biology (*32*), the language capacity appears to be both constrained and flexible. It is internally constrained with regard to the structures that it can realize (phonetic and syllabic units), yet, in the face of environmental variation, it appears to be flexible with regard to the expressive modality it can adopt to realize this capacity (signed or spoken).

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14. Videotaped sessions commenced with a period in which the infant and parent played freely. Then there was an elicitation task, in which common baby toys were held in the infant's sight but out of reach for 10 s and then were given to the infant. Finally, each infant was observed in solitary play. Sessions were conducted in the infant's native language (signed or spoken).
15. Vegetative sounds, such as crying or belching, are not transcribed because they are unrelated to an infant's prelinguistic development.
16. Manual activities such as scratching or eye-rubbing were not transcribed (*15*).
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18. "Used referentially" refers to manual activity that was used in relation to a referent in the world. "Used communicatively" refers to manual activity that was produced with clear communicative intent (fixed eye gaze at adult). The term "has conventional meaning" refers to manual activity with established cultural meaning that was not the standard sign in ASL. For example, the manual activity used to convey the concept "quiet" (index to pursed lips while producing a "shhh" sound) is used by children and adults (deaf and hearing) to indicate "quiet," but the sign QUIET in ASL is produced with an entirely different handshape and movement.
19. We further transcribed the data utilizing a notational system analogous to the International Phonetic Alphabet for spoken languages [W. C. Stokoe, D. C. Casterline, C. G. Croneberg, *A Dictionary of American Sign Language on Linguistic Principles* (Linstok Press, Silver Spring, MD, 1976)].
20. As in spoken languages, signed languages are constructed from a finite set of meaningless units (phonetic units); the subset of units used for production of a particular language is its phonetic inventory. ASL's phonetic inventory is drawn from the four parameters of a sign—handshape, movement, location, and palm orientation—each of which contains a restricted set of phonetic units (for example, a set of handshapes, a set of movements). Phonetic units are further organized into structured units called syllables [S. K. Liddell, *Language* **60**, 372 (1984)]. A well-formed syllable has a handshape, a location, and a path movement (change in location) or secondary movement (change in handshape or orientation). This yields at least four syllable types: (i) path movement, (ii) secondary movement (handshape change), (iii) secondary movement (orientation change), and (iv) path and secondary movement combined.
21. One of each infant's three videotapes (selected across all three ages) was transcribed by two coders. Reliability was calculated based on coders' percent agreement on whether a manual activity had occurred and on the precise content of a manual activity; thus, the full range of infant manual activity is represented in the figures provided.
22. Unlike words or signs, gestures (i) had unrestricted forms; (ii) violated natural-kind boundaries (events, objects, possessions, and locations) typically ob-

served in hearing [J. Huttenlocher and P. Smiley, *Cognit. Psychol.* **19**, 63 (1987)] and deaf infants; (iii) were used in communicatively restricted contexts (typically requests); and (iv) showed no semantic or structural developmental progression (*17*).
23. Just as hearing infants do not babble in specific languages (*10*), deaf infants do not babble in ASL or any other sign language. Deaf infants acquiring two distinct sign languages (ASL and Langue des Signes Québécoise) also use a common subset of possible phonetic units [L. A. Petitto and P. F. Marentette, in preparation; L. A. Petitto, *Cognition* **27**, 1 (1987)].
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26. Percent reduplicated vocal babbling has not been reported to our knowledge.
27. This ratio is divided by 35 instead of 32 because some instances of manual babbling involved more than one handshape.
28. That infants produce occasional babbling forms in the modality that does not carry linguistic input appears to be the vestige of their potential to have produced language in either modality. This babbling is unproductive because of the lack of systematic input.
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