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Language Development in the First Year of Life: What Deaf Children Might Be Missing Before Cochlear Implantation

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Objectives: Language development is a multifaceted, dynamic process involving the discovery of complex patterns, and the refinement of native language competencies in the context of communicative interactions. This process is already advanced by the end of the first year of life for hearing children, but prelingually deaf children who initially lack a language model may miss critical experiences during this early window. The purpose of this review is twofold. First, we examine the published literature on language development during the first 12 months in typically developing children. Second, we use this literature to inform our understanding of the language outcomes of prelingually deaf children who receive cochlear implants (CIs), and therefore language input, either before or after the first year.
Conclusions: During the first 12 months, typically developing infants exhibit advances in speech segmentation, word learning, syntax acquisition, and communication, both verbal and nonverbal. Infants and their caregivers coconstruct a communication foundation during this time, supporting continued language growth. The language outcomes of hearing children are robustly predicted by their experiences and acquired competencies during the first year; yet these predictive links are absent among prelingually deaf infants lacking a language model (i.e., those without exposure to sign). For deaf infants who receive a CI, implantation timing is crucial. Children receiving CIs before 12 months frequently catch up with their typically developing peers, whereas those receiving CIs later do not. Explanations for the language difficulties of late-implanted children are discussed. **Key Words:** Cochlear implants—Communication foundation—Infants—Language outcomes.

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Language is essential for the human ability to think, remember, plan, and communicate. More than a mere system of symbols or words (e.g., *cabbage*, *Jim*), the essence of language is its exceptional efficacy in expressing relations, such as, ''Jim, don't sit the babies in the cabbage,'' or ''Jim, the babies don't like cabbage.'' By the end of their first year, typical children have forded a number of hurdles on their language acquisition journey. They have discovered meaningful and reliable patterns within the speech stream (1) or the visual sign stream (2). They have extracted nonlinguistic units (e.g., actions, objects, feelings [3–5]), and have begun to uncover connections between language and the world (6–8). As babbling transitions into expressive language, infants have also recognized patterns in their prelinguistic utterances and have related these sounds (or signs) to the mature, reliable, and meaningful words of adults (9,10). Importantly, infants' ability to capitalize on perceptual information for language acquisition depends on effective verbal (11) and nonverbal (12,13) communication within the parent–infant dyad (14).

The first year of life is a crucial period for infants and their caregivers to coconstruct a communication foundation using gaze, vocalizations, and gestures in dynamic interactions (14). Language learning occurs in the context of infants' communicative interactions, and the quality of these interactions strongly predicts later language abilities (11,15,16). For some children, the quality of these early interactions is, however, tenuous. In particular, one to two per 1,000 infants are born with bilateral sensorineural hearing loss (17), and 96% of those infants have two hearing parents (18). The majority of deaf infants therefore have little to no initial linguistic experience (i.e., speech or sign). Multimonth trials with hearing aids typically precede consideration of a cochlear implant (CI; an electronic device that stimulates the auditory nerve to provide the perception of sound), and implantation is not indicated by the Food and Drug Administration until 12 months of age (19). Although CI implantation before 12 months (i.e., as young as 6 mo) is gaining traction (20,21), insurers often do not authorize CI surgery before this arbitrary age-based criterion; thus, wide variability in implantation

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times and language outcomes of CI-implanted children remain (22–24).

Language acquisition is a multifaceted process that begins in the womb. This review examines early language development in typically developing hearing children, highlighting the key linguistic achievements of the first year. We emphasize the critical experiences leading up to these achievements that may be unavailable to deaf infants and end with a consideration of children who receive cochlear implants and their language outcomes. Of course, children who fail to be diagnosed as hard-of-hearing and receive hearing aids later than the first 6 months face similar challenges. Given the increasing use of cochlear implantation, and the likelihood of language deprivation before implantation, we focus on this case.

SEGMENTING CONTINUOUS INFORMATION FROM AUDITORY, VISUAL, AND AUDITORY-VISUAL SOURCES

The infant's world is replete with continuous streams of sensory information, from the tactile sensations of diaper changes to the infant-directed speech of an adoring parent. Learning a language requires discovery of particular pairings between individuated chunks of multiple dynamic streams (i.e., words or signs paired with meaningful sensory information). Even before these pairings are formed, infants begin segmenting the constant flux of information into reliable, recognizable patterns that are meaningful for language.

Processing the speech stream begins before birth, as soon as the auditory system becomes functional at approximately 25 weeks gestation (25). Neonates are sensitive to the rhythmic patterns of speech (26) and to statistical cues, such as the greater likelihood that the syllable ''bee'' will be preceded by ''bay'' than by ''go,'' indicating that ''bay-bee'' is a word whereas ''go-bee'' is not (27). They can also already distinguish: 1) the sounds of their mother's native language from the sounds of other languages (28–30), 2) their mother's voice from the voice of other adults speaking the same language (28,31), and 3) speech content that is familiar (e.g., a nursery rhyme recited by their mother) from similar, but unfamiliar content (32,33).

Speech segmentation abilities become more specialized and refined over the first year of life. During this time, infants' ability to distinguish nonnative phonemes declines, whereas their discrimination of native phonemes improves (34–36). Infants also acquire parsing heuristics based on prosodic stress in their native language; for example, 7.5-month-old English-learning infants can segment the more common strong/weak bisyllabic units (e.g., ''*cray*on''), but not weak/strong units (e.g., ''*surprise*''; (37)). Six-month olds can isolate novel words that follow familiar words (e.g., their own name (38)), and this ability improves substantially by 12 months (39). Importantly, language comprehension at 2 years is robustly predicted by these early linguistic skills, including 7-month-olds' native phonetic discrimination (40), 6- to 9-month-olds' sensitivity to prosody (1), and 7.5- to 12-month-olds' recognition of familiar words in fluent speech (1).

In addition to segmenting the speech stream, infants must segment their nonlinguistic experiences (5) to match these experiences with language (for review see 3). By 8 months, infants can form basic-level object categories such as ''dog'' and ''cat'' (41), as well as event categories, such as ''occlusion'' (i.e., when an object moves behind a barrier) and ''containment'' (i.e., when an object is placed inside a container) (42), *without* yet having labels for each category. Nonlinguistic segmentation mechanisms are similar to those used for the speech stream. Given only visual stimuli, infants track statistical regularities in continuous events by 7 to 9 months (43,44) and recognize familiar actions embedded in novel events by 6 to 8 months (45).

Finally, infants also discover multimodal patterns in the audio-visual stream that support language development. Intersensory redundancy occurs when the same information is simultaneously available to two or more sensory systems (e.g., visual and auditory (46)). Many events meet this criterion, such as hearing and seeing a door close. During the first year, redundantly specified properties (e.g., rhythm) are more perceptually salient than unimodal ones (e.g., color (46)). Focusing on redundant properties is important for constraining early perceptual learning and developing attentional selectivity (46,47). In particular, audio-visual speech synchrony leads infants to shift their focus from a speaker's eyes to her mouth, between 4 and 8 months of age (48). By 12 months, infants return to focusing on the speaker's eyes, presumably because of expertise with native speech audio-visual synchrony and the search for social cues (48). Importantly, infants who fixate more on their mother's mouth during interactions at 6 months have better language outcomes in the second year (49).

MAPPING WORD TO WORLD

Although segmenting continuous sensory information is vital for language development, it is only the first step. Infants must also learn to map individuated word forms onto individuated real-world referents. Whenever a child encounters a new word, she must disambiguate among many possible meanings (50). Studies have shown that children rely on a combination of perceptual (51,52), social (53,54), and linguistic cues (8,55,56) to settle on the correct meaning of a word. Interestingly, these cues are weighted differently throughout the course of development (7,57), with early word learning establishing the groundwork for later development.

As early as 6 months—before producing their first word—infants link words to specific entities (e.g., ''mommy'' (58)) and to familiar objects (e.g., ''banana'' [59,60]). By 10 months, they can learn two new words in one sitting, but pay little attention to relevant social-pragmatic information (61). Pruden et al. (61) found that 10-month olds systematically map novel words to perceptually salient objects even when there is conflicting social-pragmatic information, as when an adult intends to label a comparatively boring object. By 12 months, infants no longer make this mismapping error, but they fail to map the novel word at all when social-pragmatic cues conflict with perceptual information (7). This failure represents progress, as infants at least notice social cues highlighting the boring object; by 19 months, they will even learn the names for unattractive referents (7). These results show that substantial differences in the weighing of word meaning cues occur during the first year.

Additionally, infants develop a preference for language over other sounds (62–64). For example, whereas 3-month-olds form object categories (e.g., fish) when presented with a series of related objects paired with either human speech or lemur vocalizations (but not sine-wave tones [63,65]), by 6 months, human sounds alone promote object categorization (65). Further, 12-month olds recognize that *speech* communicates information about an object, and that nonlinguistic human noises, such as coughing, do not (63,64). Yet typically developing 12-month olds retain some flexibility in word learning; given adequate referential cues, they will map a variety of symbols to objects, including gestures (66), nonnative language (67), and even novel nonspeech sounds (68). This flexibility is maintained until 20 to 26 months (66–68), indicating that language experiences during and beyond the first year contribute to the narrowing of mapping selectivity.

FINDING SYNTACTIC PATTERNS

While word learning is underway, infants begin to discover abstract syntactic patterns. Infants exposed to English, for example, must learn that adjectives precede nouns whereas those exposed to Spanish learn the opposite ordering. As in the phonological domain (1,34–36,40), sensitivity to structural information becomes more specialized to the child's native language over time (69) and is critical for language acquisition (70,71).

Mandel et al. (72) found that 2-month olds already recognize word order patterns and do so more readily from full sentences than from sentence fragments. Seven-month olds can detect arbitrary algebraic word ordering rules, which cannot be learned by counting or from transitional probabilities, but instead represent ''open-ended abstract relationships'' (73). By 8 months, infants become sensitive to the particular word ordering rules of their native language (74), gradually forming hierarchical rules to represent syntactic patterns (75). Infants also develop sensitivity to syntactic frames, recognizing clausal boundaries in their native language by 7 to 10 months (76) and phrasal boundaries by 9 months (77).

Experiences with prosodic information and statistical patterns during the first year contribute to infants' syntax acquisition. If exposed to an artificial language with similar prosody to natural language, infants prefer their native word order to nonnative ones (78). Marquis and Shi (79) found that 11-month olds use high-frequency morphemes to recognize novel words. In their study, French infants were exposed to novel verbs ending in the suffix /-e/, which frequently follows French verb roots. Recognizing this common suffix, infants could segment novel verb roots just like native ones. By 12 months, infants use statistical patterns in familiar word orderings to determine the grammaticality of novel constructions (80). Infants at this age also begin integrating various types of information to interpret syntactic structure (81,82).

COMMUNICATING VERBALLY AND NONVERBALLY

Infant–parent communication involves a dynamic series of bids and responses. Importantly, communicative experiences progress rapidly after birth (83,84). Neonates spontaneously produce primitive vocalizations, and the rate of these vocalizations increases as a function of parent talk, even among infants born preterm as early as 32 weeks (83). Similarly, full-term and preterm 7-month olds make gains in gaze following at comparable rates, as a function of their experience with face-to-face interactions rather than gestational age (84). Because joint engagement and parental responsivity to the child's focus of attention both predict language growth (53,54,85,86), meaningful communication is vital from birth.

Parents' verbal and nonverbal responses to infants' behaviors provide a critical first step to constructing a communication foundation (53). Parents naturally modify their speech to accord with the vocal abilities and specific vocalizations of infants (87,88). The contingent feedback adults provide leads to constant refinements of infants' vocal repertoires (89) and by 5 months, infants have learned that their vocalizations influence the social behavior of others (90–92). Additionally, parents capitalize on infants' perceptual interest (e.g., focusing on a specific toy), by providing labels for salient objects (7,93,94). Language comprehension during the second year of life is predicted by parents' ability during the first year to redirect infants' attention (95) and to respond appropriately to infants' object of interest (16).

Over the first year of life, infants begin to integrate verbal and nonverbal information to bolster language learning. At 6 months, infants recognize eye contact with an adult as an important ostensive signal, and use this cue to follow the adult's gaze toward an object (96). The ability to follow an adult's gaze and the duration of that gaze at 10 to 11 months predicts language scores in the second year of life (12,13). In addition, the ability to simultaneously vocalize and point to redirect parental attention at 10- to 13-month-olds predicts language comprehension at 15 months (16). By 12 months, infants learn words more readily when objects are labeled in response to their object-directed vocalization rather than after object-directed gaze alone (97). This combination of verbal and nonverbal communication in the infant–parent dyad sets up a communication foundation that is critical for language development throughout the first year and beyond (14,98); as with later development, both the quantity and quality of input matter (14,99,100).

SUMMARY: LANGUAGE ACQUISITION IN THE FIRST YEAR

Although typically developing 12-month olds are just beginning to produce their first words, research probing beneath the surface reveals significant advancements in language acquisition by this time. Over the course of the first year, infants' growing familiarity with their native language leads them to process the speech signal, map words, and learn syntax in an increasingly specialized manner. This increasing familiarity occurs in the context of infant–caregiver interactions; caregivers' responsivity and contingent linguistic feedback to infants' expressions of interest begin to build a communication foundation for language development.

CIs BEFORE AND AFTER 12 MONTHS

The research reviewed above demonstrates the continuity from prelinguistic competencies emerging in the first year of life (e.g., pattern discovery; vocal and nonverbal communication) to later language-specific abilities. Measures of prelingually deaf infants' communicative skills during the first year (i.e., Communication and Symbolic Behavior Scales) are, however, comparatively poor predictors of language skills following experience with CIs (101).

Infants with CIs do show clear continuity from their vocalization abilities 6 to 9 months after CI implantation (but not earlier) to their global language skills (i.e., comprehension, expression) at age 4 (102). However, beyond this continuity, there are tremendously wide end states among children with CIs (e.g., 101). A key factor determining children's ability to ''catch up'' to their typically developing peers is the timing of cochlear implantation (103–105). Specifically, a growing body of literature reveals a cutoff at approximately 12 months, with infants receiving CIs before this time significantly outperforming infants receiving CIs after this time on a variety of language outcome measures (103–109) but see (110) for a metaanalysis indicating more evidence is needed). Indeed, whereas older research suggested that the critical period for language acquisition ended at puberty (111,112), newer research suggests that missing out on input in the first year of life is associated with a decline in neural plasticity that has long term effects (113,114). Hints that this may be the case are found in research by Gauthier and Genesee (115) on internationally adopted children from China. Despite the fact that children were adopted at mean age 16 months and fell into the normal range on language tests years later, they still lagged behind their native language peers, especially in morphology and syntax (115).

Research examining children with CIs reveals that whereas speech perception outcomes are largely similar for deaf children implanted before 13 months and those implanted between 16 and 23 months, *vocabulary* outcomes are substantially worse for children implanted during the latter window (116). *Grammar* outcomes in late-implanted children are similarly poor (117,118).

Why are vocabulary and syntax acquisition so challenging for late-implanted infants? It is not because of difficulty forming prelinguistic concepts; even deaf children with no exposure to conventional language systems express, through gesture, similar nonlinguistic categories as hearing children (119), suggesting that they segment the continuous nonlinguistic world in a typical manner. Rather, late-implanted infants face particular challenges learning novel word-object pairings (104,108) and grammar sequences (120).

Broadly, there are four key explanations for these difficulties. First, language competence may be mediated by children's speech perception skills, as Werker and Hensch (121) argue. They posit a series of overlapping critical periods for different aspects of phonological development, all of which ordinarily take place in the first year of life. For example, a critical period has been posited between 0 and 4 months for distinguishing between languages, followed by a period from 2 to 12 months for narrowing perception to one's native phonetic categories. Each critical window has cascading effects on the next, such that children who develop one skill later are bound to develop the next skill later. Because late-implanted children begin learning phonology after these critical windows have passed, their brains may have already been affected by the lack of auditory stimulation (121).

Differences in experience-based domain-general cognitive alterations (i.e., selective attention and sequencing skills) offer another explanation of late-implanted children's language deficits (122,123). CI-implanted children have difficulties with selective visual attention (123), possibly resulting from the absence of early experiences with audio-visual synchrony, which facilitate selective attention and word learning in hearing infants (46,47). Similarly, sequence learning difficulties in CI-implanted children (120,122), and their corresponding impairments in recognizing words in context (124), may be attributed to a dearth of early experiences using implicit statistical learning to parse the speech signal (125).

A third factor contributing to language deficits in these children is the potentially reduced communication foundation with primary caregivers (126–128). Fagan et al. (127) found that mothers of CI-implanted children use more directives (e.g., *let go*, *come here*) and prohibitions (e.g., *no*, *don't touch*) than mothers of age-matched hearing children before and 7 months after CI implantation, demonstrating continuity in an impaired foundation. Mothers of CI-implanted children also use less complex utterances, suggesting a reduced language environment (127). However, mother–child dyads show improved communicative synchrony following implantation (127), with mothers modifying their speech to their child's auditory stage rather than their chronological age

(129,130) and adopting supplementary strategies to direct their child's visual attention (128). Moreover, individual differences in maternal linguistic input to late-implanted children, including measures of quantity (i.e., mean length of utterance and word types) and quality (e.g., use of open-ended questions), are strongly linked with receptive and expressive language skills (126). This parallels findings in typical language development (14,99,100), suggesting that certain strategies may offset the challenges these children face such that infant–parent dyads can rebuild a communication foundation following implantation.

Finally, a fourth and critical explanation for the language deficits in late-implanted children is their increased sensitivity to the vagaries of their language environment compared with early-implanted or typically developing children. Suskind (131) argues that the range of outcomes among CI-implanted children refutes the assumption that CI-enabled hearing invariably supports language acquisition. Language environments vary from linguistically and conversationally rich to exceedingly poor (14,99,100) and these environmental qualities may be particularly important to children with degraded processing abilities. For example, parent speech is a more powerful predictor of language development for children with brain injuries than for typically developing children (98,132). This pattern may also hold for late-implanted prelingually deaf children, with the negative effects of early language deprivation compounded by the exaggerated negative effects of a language-poor environment.

CONCLUSION

Crucial experiences for language acquisition occur during the first 12 months of life. The speech signal is parsed, words are mapped to real-world referents, and syntactic patterns are discovered as infants begin coconstructing a communication foundation with their caregivers. Many of these vital experiences are initially absent in the lives of prelingually deaf infants. In fact, a growing literature reveals a significant divide in the language outcomes of children receiving a CI before 12 months and those receiving the implant later. Bringing this early window into focus highlights the fascinating and rapidly expanding language capabilities of typically developing infants, as well as the language deprivation experienced by late-implanted prelingually deaf children.

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