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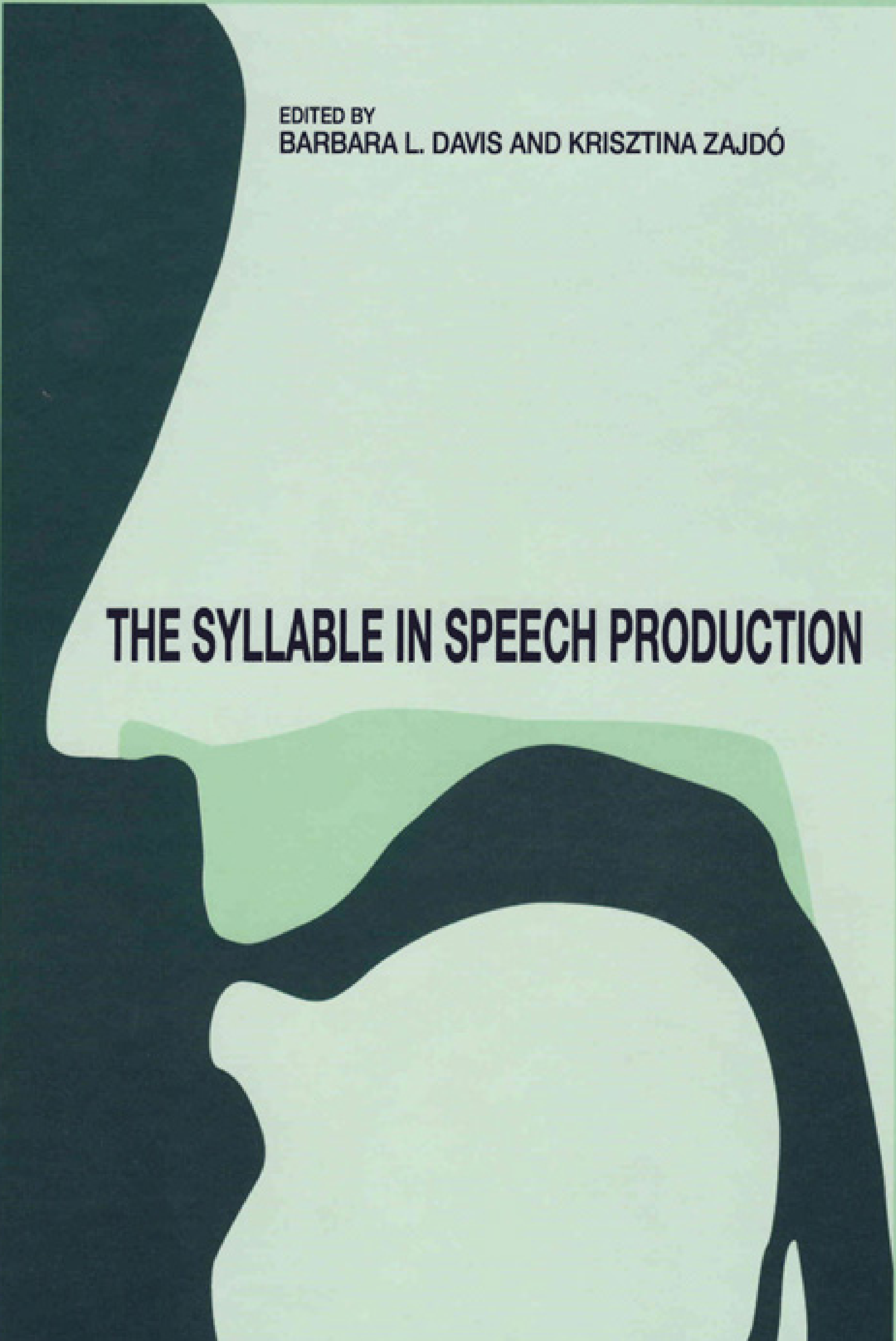
THE SYLLABLE IN SPEECH PRODUCTION



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Co-occurrence Patterns in the Babbling of Children with a Cochlear Implant *

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Background

Prelexical babbling represents an important achievement in children's vocal development. Although the characteristics of babbling (i.e., onset, segmental content) have been studied intensively in the last twenty years or so, it still remains unclear to what extent this prelexical development is autonomous or driven by auditory input and feedback.

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Studies of children's motor development seem to imply that the *onset* of babbling is an autonomous event and a motor milestone. Koopmans-van Beinum and van der Stelt (1986) found a particular order in the development of motor functions (including rolling from prone to supine, crawling, pulling up, etc.) in 51 normally developing children. Babbling occupies a specific position in that order. Other studies have argued that the onset of babbling represents a specific step in infants' overall rhythmic development. For instance, Thelen (1981) found a peak period of rhythmic hand-banging around the age of 6-7 months, the age at which babbling normally takes off.

Similarly, the *content* of babbling has been described as autonomous, viz. a direct result of the production of rhythmic mandibular oscillation (Davis & MacNeilage, 1995; MacNeilage & Davis, 1990a, 1990b): the oscillation of the mandible appears to be an independent rhythm generator in babbling. This theory is called the "Frame Dominance Theory" (henceforth: FDT), in which the term "Frame" applies to the regularity of mandibular oscillation accompanied by phonation resulting in the production of syllable-like output. Elevation of the mandible results in a consonant-like sound, while depression of the mandible results in a vowel-like sound. In this way, babbling (and early speech) is hypothesized to be based on rhythmic close-open movements or cycles of the mandible accompanied by phonation. The dominance of the "Frame" is considered to result from the virtual absence of an active role of articulators other than the mandible during babbled utterances. Each of the active articulators (i.e., tongue, lips, soft palate) is considered either to remain in resting position during the entire babbling utterance, or to assume a non-resting position at the beginning of the babbling utterance and to retain this position throughout. As a result of this pattern, serial interdependence is considered a hallmark of babbling utterances. This interdependence appears in its most obvious form in the strong trends toward concurrence of consonants (C) and vowels (V). There are two types of interdependency: intracyclical (between adjacent C's and V's) and intercyclical (between two adjacent CV syllables).

Intracyclically, three types of CV co-occurrence constraints are predicted based on FDT: a coronal consonant with a front vowel ("fronted" frames), a dorsal consonant with a back vowel ("backed" frames), and a labial consonant with a central vowel ("pure" frames: production by mandibular oscillation alone, without tongue preconfiguration). MacNeilage and Davis' (e.g., 1990a, 1990b) explanation for these co-occurrence patterns is the presence of a basic biomechanical constraint against tongue movements in the front-back dimension in the transition from the consonant to the vowel. These co-occurrence patterns are also characteristic of children's first words in English (Davis, MacNeilage, & Matyear, 2002) and in other languages studied (see Davis & MacNeilage, 2000 for a review).

Intercyclically, FDT has also implications for patterns of variegated babbling. FDT predicts a significantly higher proportion of changes in the vertical dimension than in the horizontal dimension for consonants as well as for vowels. This patterning is predicted based on the proposed predominance of mandibular over lingual movements in early canonical babbling. These changes in the amplitude of the mandibular cycle result in a stronger trend toward height over front-back dimension changes for vowels (e.g., /dædi/) and in manner over place changes for consonants (e.g., /bawa/).

MacNeilage, Davis, Kinney, and Matyear (1999) also found that the preferred CV co-occurrence patterns in babbling and early words are a recurrent typological pattern. Analyses of intrasyllabic trends in 10 typologically diverse languages revealed that the observed frequencies exceeded the expected frequencies of labial-central CV pairs in 7 languages, coronal-front CV pairs in 7 languages, and dorsal-back CV pairs in 8 languages.

In summary, production based physiological explanations suggest that at the onset of babbling, the serial organization of CV co-occurrences within syllables, and the across syllable variation patterns are not influenced by audition, but are controlled by motor constraints that apply to normally hearing (henceforth: NH) children as well as to hearing-impaired (henceforth: HI) children. The predictions of this theory have been confirmed in NH children supported by an increasing amount of evidence. However far less evidence is available for HI children. Available evidence on these children with differing access to the auditory speech signal does not unequivocally support a physiologically based theory such as FDT. With regard to the *onset* of babbling, a pure production system based physiological explanation cannot account for the substantial delay of 15-18 months found in profoundly HI infants (Koopmans-van Beinum, Clement & van den Dikkenberg-Pot, 2001; Oller & Eilers, 1988). Most HI children produce repetitive vocalizations, but these mainly consist of multiple V syllables without C's (Koopmans-van Beinum et al., 2001). Babbles with multiple CV syllables tend to occur only sporadically (less than 20% according to Oller & Eilers, 1988), and their frequency decreases with age in contrast to a clear increase (i.e., the babbling spurt) seen in NH children. McCaffrey, Davis, MacNeilage, and Von Hapsburg (1999) reported the case of an English-learning child who received a cochlear implant (henceforth: CI[1]) at 25 months. At 7 and 9 months after implantation, a significant increase of syllabic productions occurred, suggesting that auditory input (by means of a CI) is necessary for the production of syllabic vocalizations. Schauwers, Gillis, Daemers, De Beukelaer and Govaerts (2004) provide evidence for the effect of auditory input and feedback on the onset of babbling: ten profoundly HI infants who received a CI before 20 months of age were followed longitudinally. The results show a linear correlation between the age at implantation and the onset of babbling. All 10 early implanted CI children started babbling within 4 months after the activation of the implant. Thus only the onset of babbling in the 4 youngest subjects occurred at a chronological age comparable to that of NH infants (viz., between

[1] A CI is an electronic device that converts the incoming acoustic signal into a coded electrical stimulus that directly stimulates the auditory nerve, bypassing damaged or missing hair cells of the cochlea. The most important difference with conventional hearing aids is the ability of a CI not only to amplify the sound but also to restore the frequency resolution of the cochlea.

8 and 11 months of age). In addition, all children with a CI demonstrated a clear babbling spurt within 9 months after the activation of the implant.

With regard to babbling *content*, von Hapsburg (2003) performed CV co-occurrence analyses in a group of 6 English-learning children with a mild-to-severe hearing impairment and in a group of 5 English-learning profoundly HI children. The analyses confirmed that when the children produced canonical syllables, the labial-central and coronal-front patterns tended to co-occur at higher rates than other within-category co-occurrence patterns in both groups, similar to NH children. In terms of intercyclical organization, C and V variegation patterns showed higher proportions of V height variegation than front-back variegation, and higher proportions of C manner variegation than place variegation, again in line with predictions of the FDT. These results held for both HI groups.

The aforementioned child who received a CI at 25 months (McCaffrey et al., 1999) also produced significantly higher than expected co-occurrences of labial-central and coronal-front CV's after implantation, which is predicted by FDT. In addition, this CI child also demonstrated the expected preference for consonantal manner variegation, but not the expected height variegation of vowels. Overall, the authors concluded that the babbling utterances after implantation evidenced basic motor propensities, similar to NH children, once the child has had enough listening experience to trigger syllable-like output.

Given the present evidence, it seems that pre-canonical vocalizations may be physiologically driven and probably do not require auditory input, whereas the onset of rhythmic syllable-like vocalizations in canonical babbling requires auditory input. Whether the content of babbling utterances also requires auditory input remains unclear. Therefore, we investigated babbling in 10 profoundly HI children in a Dutch language environment who received a CI between 5 and 20 months of age. The basis of comparison is the babbling of 10 NH children from the same language environment. Several questions will be considered in this report: (1) Do CI and NH children differ from each other in the types of syllabic patterns they prefer to produce?; (2) Is the distribution of intra- and intersyllabic babbling patterns in these CI and/or NH children consistent with the predictions put forward by the FDT?; and (3) If not, do we see an influence of the environmental language on children's syllabic structure preferences?

Method

Participants

All study participants live in Flanders, the Dutch speaking part of Belgium. The study group consisted of 10 congenitally deaf children of hearing parents without other health problems such as cognitive or motor delays. The children's hearing loss was detected in a neonatal screening program within the first month of life, and a profound hearing impairment (i.e., an unaided pure-tone average or PTA of more than 90 dBHL in the better ear) was confirmed by auditory brain stem response in the first weeks of life. In 7 cases, the cause of deafness was genetic (5 of them were mutations in the connexine-26 gene, which is a commonly found cause of congenital deafness). Nine infants received bilateral hearing aids within 1-4 months after detection of the hearing loss, one child at 8 months after detection. After wearing the hearing aids for several months without any progress (only one child reached a PTA within the speech area with his hearing aids, viz., 47 dBHL), all children received a multichannel Nucleus-24 CI (Cochlear Corp., Sydney, Australia) between 5 and 20 months of age. The PTA with the CI, as measured by pure-tone audiometry at the age of 2 years, increased to 28 – 53 dBHL, and all children were able to discriminate a set of speech sound contrasts immediately after activation of the implant as assessed by means of the Auditory Speech Sound Evaluation (A§E®, P.J. Govaerts, Antwerp-Deurne, Belgium). All children were raised orally with support of a limited number of signs. Table 1 gives an overview of the auditory characteristics of the CI children.

A control group of 10 NH children of hearing parents was selected, and informed consent from the parents to participate in this study was obtained. This group was followed starting at a chronological age of 6–8 months. The recordings were discontinued as soon as the child produced at least 50 word types as assessed by the Dutch MacArthur CDI vocabulary list (Zink & Lejaegere, 2002) (range 1;6–1;10). One NH child dropped out at the age of 0;11. No health or developmental problems were present in these NH children.

Table 1.
Overview of the auditory characteristics of the CI children.

Subject	PTA unaided (dBHL)	PTA aided (dBHL)	PTA with CI (dBHL) at age 2;0	Age at implantation	Age at activation
RX	117	107	42	0;5.5	0;6.4
AN	120	120	30	0;6.21	0;7.21
MI	120	108	53	0;8.23	0;9.20
YA	103	63	28	0;8.21	0;9.21
EM	115	113	33	0;10.0	0;11.20
RB	117	77	43	1;1.7	1;2.4
AM	120	120	48	1;1.15	1;2.27
KL	93	47	38	1;4.27	1;5.27
JO	113	117	48	1;6.5	1;7.9
TE	112	58	38	1;7.14	1;9.4

Data Collection and Transcription

In order to monitor the prelexical period in the CI and NH children, we relied on monthly video recordings taken at their homes. Digital recordings of approximately 60-80 minutes were obtained starting from the first month after activation of the cochlear implant in the case of the CI children, and from the chronological age of 6-8 months in the case of the NH children. Six CI children were also recorded once before implantation. The video sessions consisted of spontaneous unstructured interactions between the child and a parent (and in some cases a sibling).

From each recording a sample of approximately 20 minutes was selected. The sampling procedure was done by the same person for all recordings and aimed at selecting delineated sequences of interactions. Subsequently, these selections were transcribed and annotated according to the CHAT conventions (MacWhinney, 2000). Transcription consisted of an orthographic transcription of the adult's utterances, and an orthographic and phonemic annotation of the lexical items of the child. For the children's prelexical utterances, a dedicated coding system was adopted, which has been described in more detail in Schauwers et al. (2004). Briefly, each vocalization (and more specifically, each 'comfort sound') was coded in terms of phonation (uninterrupted or interrupted) and articulation (no articulation, one articulation, or 2+ articulations) according to the model proposed by Koopmans-van Beinum et al. (1986). Each utterance also received a CV-code, i.e., the utterance was broken up into a sequence of consonant- and vowel-like elements. The characteristics of each segment – C or V – were defined in terms of the place and manner of articulation for consonant-like elements, and in terms of the height and the front-back dimension for vowel-like elements. In most cases, the video images provided additional visual information to determine the segmental characteristics.

The Age Period Studied

For each CI and NH participant, data analysis was initiated when the child started canonical babbling, and ended when the child produced at least 10 word types. To determine the age at which the child produced at least 10 different words, we followed the procedure for identifying words proposed by Vihman and McCune (1994). Henceforth, this period is referred to as the *babbling period*.

The onset of babbling in these 10 CI and 10 NH children was reported in Schauwers et al. (2004). The NH children started babbling between 6 and 8 months of age, and the CI children started babbling between 8 and 21 months of age. The CI children produced their first 10 words between the ages of 17 – 26 months. This resulted in a median of 7.5 sessions used for data analysis in the CI group. The NH children reached their 10-word stage between 14 and 20 months of age, resulting in a median of 11.5 sessions for data analysis. One NH child discontinued participation in the study after 6 sessions (from 6 to 11 months of age).

In this paper we will report data of the children's babbling from the onset of babbling up to the 10-word point. For the NH children our database consists of 14,918 babbled syllables (average: 1,492; range: 645–2,643) and 11,921 babbled syllables from CI children (average: 1,192; range: 276–2,354).

Analysis of the Serial Organization of Babbling

Intrasyllabic Co-occurrences

For the analysis of CV co-occurrence patterns, all CV syllables in the corpus of the CI children and the NH children were selected, independently of their position within an utterance. The consonant in each CV syllable was coded in terms of its place of articulation (coronal, labial, dorsal). Vowels were coded as front, central, or back. This approach yielded a 3x3 matrix reflecting the 9 possible co-occurrences of C and V.

In order to assess the predominance of particular CV co-occurrences, we used the same approach as Davis and MacNeilage (1995): the actual prevalence of each CV co-occurrence was compared to its "expected prevalence". The expected prevalence of a CV co-occurrence was calculated from the overall frequencies of the individual consonants and the individual vowels in the corpora (= (row total x column total) / total of observed CV's). This result represented the prevalence that a specific CV occurs in case of a completely random combination of C's and V's. If the child prefers to use a particular CV sequence rather than other combinations, the observed prevalence of this CV would be higher than the expected prevalence and the ratio of the observed prevalence to the expected prevalence would be higher than 1. This ratio was used to test the FDT proposed by MacNeilage and Davis (1990a, 1990b; Davis & MacNeilage, 1995): three of the 9 possible types of CV co-occurrences are predicted to be produced preferentially during babbling, viz. coronal consonants with front vowels (e. g., /ti/), labial consonants with central vowels (e.g., /ma/), and dorsal consonants with back vowels (e.g., /ku/).

Statistical analyses were used to test whether the observed prevalence of each CV-occurrence differed significantly from its expected prevalence. To obtain these results, we converted the binomial parameters (N = total number of CV-occurrences for one child, p = expected prevalence of a CV-occurrence) into the parameters of a normal distribution with a mean = N*p and a standard deviation = $\sqrt{(N*p*(1-p))}$. This conversion yielded a z-value for each observed CV pattern. The cut-off level for significance was set at 0.05 ($-1.96 < z < 1.96$). Statistical analyses were also used to test whether the observed prevalence of the different CV patterns was different between the NH and CI subjects. To calculate these results, Mann-Whitney U tests were performed with a cut-off level of significance of 0.05.

Inter-syllabic Patterns

The analyses of inter-syllabic patterns were carried out to determine how consonants (place versus manner) and vowels (height versus front-back dimension) varied from one CV syllable to the next. Therefore, all possible pairs of successive CV syllables in the corpora of the CI and NH children were selected. In utterances with more than two syllables, each syllable, except the first and last one, was analyzed twice: once as the first of two syllables and once as the second. If the two syllables were the same, the sequence was characterized as reduplicated. A variegated sequence was defined as a CVCV sequence in which the consonants or the vowels or both were different from each other with regard to place and/or manner of articulation for the C's, and front-back dimensions and/or height for the V's. Voicing differences were not considered.

FDT makes two clear predictions about inter-syllabic variegation patterns: (1) for V's, higher proportions of V height changes are expected than front-back changes; and (2) for C's, more manner variegation is expected than place variegation. A Wilcoxon matched pairs test was carried out to evaluate these predictions within each group (NH and CI). A Mann-Whitney U test was used to investigate whether the observed variegations were different between the NH and the CI group. Cut-off levels of significance were set at 0.05 for all tests.

Results

Intrasyllabic Co-occurrences

The co-occurrence matrix of intrasyllabic CV correlations during the babbling period of the NH children and the CI children are given in Table 2. The table displays ratios of observed / expected prevalences: the rows represent the articulation places of the C's (coronal, labial or dorsal) and the columns the front-backness of the V's (front, central or back). Black fields mark ratios that are statistically significant from 1 ($p<0.05$); double asterixes (**) mark ratios that are predicted to be higher than one according to FDT.

Table 2.

Intrasyllabic CV co-occurrence ratios in the babbling of 10 NH and 10 CI children.

	Front	Central	Back
NH			
Coronal	** 1.2 **	1.0	0.7
Labial	0.7	** 1.0 **	1.4
Dorsal	1.1	1.1	** 0.7 **
CI			
Coronal	** 1.6 **	0.8	0.7
Labial	0.5	** 1.2 **	1.4
Dorsal	0.8	1.3	** 0.9 **

For both the NH and the CI group, significantly more Coronal-Front and Labial-Back co-occurrences were observed than expected and significantly less Labial-Front and Coronal-Back co-occurrences were observed than expected. No significant between-group differences were found when comparing the NH and CI children.

Intersyllabic Patterns

Table 3 and Figure 1 show the types of intersyllabic variegations in the NH and the CI children. The NH children show significantly less C variegation than V variegation ($p<0.05$) or mixed variegation ($p<0.01$). Similarly, the CI children

Table 3.

Types of intersyllabic variegations in the NH and the CI children (median values).

	NH	CI
Vowel	32%	46%
Consonant	24%	21%
Both	41%	28%

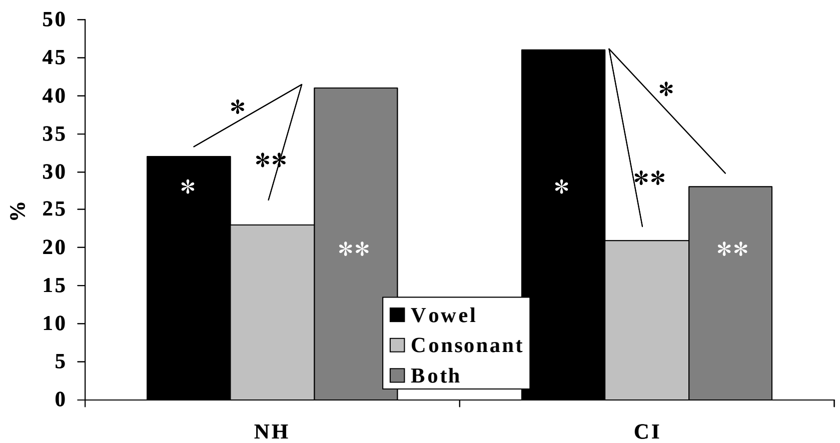

Figure 1.

Types of intersyllabic variegations in the NH and the CI children. * and ** mark significant within-group differences at $p<0.05$ and $p<0.01$. White * and ** mark significant between-group differences at $p<0.05$ and $p<0.01$.

show significantly more V variegation than C variegation ($p<0.01$) or mixed variegation ($p<0.05$). The CI children show significantly more V variegation than NH children ($p<0.05$) and significantly less mixed variegation ($p<0.01$).

Table 4 shows the types of intersyllabic C (manner or place) and V (height or front-backness) variegations. In case the intersyllabic variegations consisted of both C and V variegation, half a count was allotted as C variegation and half as V variegation. In both groups (NH and CI) manner variegation is predominant for C's ($p<0.05$) as predicted by FDT. However, findings about the front-back variegation for V's ($p<0.01$) contradict the prediction set forth by the FDT. No statistically significant differences were found between the NH and CI groups. The CI children showed less combined C variegations (place AND manner) than the NH children (25% and 35%, respectively), but this difference was not statistically significant.

Table 4.
Types of intersyllabic consonant and vowel variegations (median values).

	NH	CI
Consonant		
Manner	58%	63%
Place	42%	37%
Vowel		
Front-Back	65%	64%
Height	35%	36%

Discussion

The present study addressed babbling of early implanted deaf children, with an emphasis on syllabic organization. Deaf children are known to vocalize similarly to hearing children. However, their canonical babbling is retarded or may not occur at all (Oller & Eilers, 1988). In a previous report it was shown that cochlear implantation can initiate the onset of babbling (Schauwers et al., 2004). In this paper, we analyzed NH and CI children's babbles in order to test some of the predictions of the FDT related to serial organization of syllable-like output.[2]

Intrasyllabic Co-occurrences

All children showed a higher than expected intrasyllabic co-occurrence of predicted coronal consonants with front vowels. However, labial consonants also co-occurred with back vowels (Table 2). In contrast, the co-occurrence of coronal consonants with back vowels was less than expected, similarly to the co-occurrence of labial consonants and front vowels. Neither of these two co-occurrences is predicted by FDT. No differences were found between the CI group and the NH group in terms of these co-occurrence patterns.

The findings in the NH group and the CI group are not in line with the FDT. The FDT predicts a high prevalence of coronal-front, labial-central and dorsal-back (the diagonal line in Table 2). Only one of these predicted co-occurrences is statistically higher than expected in both groups (viz., coronal-front). The dorsal-back co-occurrence pattern tends to be less prevalent than expected, although again without statistical significance. The ratio is less than 1 in 8 out of 10 NH children and in 7 out of 10 CI children. The other 6 co-occurrence patterns should occur less than expected according to the FDT. This is only the case in 2 of these 6 co-occurrences (viz. the coronal-backs and the labial-fronts). The other co-occurrences have expected prevalence with a ratio of about 1.0. Hence, the strongest unpredicted pattern relative to expectations of FDT is the labial-back co-occurrences (with a ratio of 1.4) in both NH and CI children ($p<0.05$). To a lesser degree, the high prevalence of dorsal-centrals do not favor the FDT either (not statistically significant in either group).

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[2] An analysis at the segmental level is presented in Schauwers et al. (submitted).

Currently, no working hypothesis exists to explain the observed prevalence of the unpredicted CV co-occurrence patterns. One possible explanation is that these patterns reflect the intrasyllabic co-occurrence patterns of the Dutch language. In order to investigate this possibility, we analyzed the CELEX Dutch lexical database (Baayen, Piepenbrock, & Gulikers, 1995). The phonemic transcriptions of all the word forms from this database (N = 347,150) were investigated, and the word form initial consonant-vowel sequences were categorized and analyzed in the same way as the babbles of our study groups. All 9 possible CV co-occurrences showed ratios that differed from 1 with statistical significance ($p<0.05$), but again not as predicted by the FDT. Two out of 3 co-occurrences that are anticipated to have a high prevalence did so, viz., the coronal-front and the dorsal-back combinations (with ratios of 1.1 for both). However, the labial-central combination had a ratio of 0.9. Similarly, only 4 out of 6 co-occurrences were anticipated to have a low prevalence did so, viz., the coronal-central, coronal-back, labial-front and dorsal-front combinations (with ratios of 0.9, 0.9, 0.9 and 0.7, respectively). The labial-back and dorsal-central combinations had ratios of 1.1 and 1.3, respectively. So whereas the CELEX-data are also not in line with the FDT, they may be able to explain the findings in the babbling of NH children. Indeed, those co-occurrences that have been observed with statistically higher than expected prevalence in the NH children, also occur more often in CELEX. This is the case for the coronal-fronts and the labial-backs. And likewise, those co-occurrences that have been observed with statistically lower than expected prevalence in the NH children, also occur less often in CELEX. This is the case for the labial-fronts and the coronal-backs.

Variegation

In both the NH and the CI children, intersyllabic V variegation occurs more often than C variegation. Isolated C variegation is relatively rare in both groups (24% and 21%, respectively; see Table 3 and Figure 1). However, due to the high number of mixed variegations of V and C, a substantial amount of C variegation was found in the NH children. Overall, 65% of the variegated babbles exhibited C variegation in this population. In contrast, the mixed type of variegation was far less prevalent in the CI children (28%, $p<0.01$). Thus, although the total frequency of V variegation was similar to that found in NH children, the total frequency of C variegation was less frequent (49%) than in NH children (65%). As mentioned in the results, the types of C and V variegation were not different between the NH and the CI group (more C manner variegation and more V front-back variegation, see Table 4). Nevertheless, less combined C variegations were seen in the CI group (25% instead of 35% in the NH group), although not statistically significant.

FDT makes two clear predictions about intersyllabic variegation patterns: (1) for V's higher proportions of V height changes are expected than front-back changes; and (2) for C's more manner variegation is expected than place variegation. Consonant variegation in NH and CI infants' babbling is well in accordance with the FDT predictions: manner variegation (58% and 63%, respectively) is more frequent than place variegation (42% and 37%, respectively). However, V variegation is not in accordance with the predictions of FDT, in either group. Both groups show a preference for front-back variegation (65% and 64%, respectively) instead of height variegation (35% and 36%, respectively).

In order to trace possible influences of the ambient language, we turned to the CELEX lexical database and analyzed consecutive syllables in the Dutch word forms that exhibit C and/or V variegation (N=406,431). The CVCV sequences were analyzed according to the same categories as the children's babbling data. In Dutch word forms, place variegation (52%) is more frequent than manner variegation (48%). Thus, although the observed C variegation in NH children corroborates the predictions of the FDT, the language that they hear does not. This type of finding supports a production system based argument over a perceptual argument. With respect to V variegation, the word forms from the CELEX database analyzed (N=397,003), revealed a picture that is quite in agreement with the predictions of FDT: height variegation constitutes 59% of all cases and front-back variegation 41%. Yet, NH children appear to prefer otherwise! How can these contradictory findings be reconciled? At present, we can only speculate on the reason. First of all, the data selected from CELEX are types, and hence all frequency data are type frequencies. It may well be the case that instead of type frequencies, token frequencies are required and that type and token frequencies provide different patterns. This topic remains to be investigated. Secondly, CELEX constitutes a database of adult written language. Although it is common practice to consult the CELEX lexical database for frequency data of all sorts, and although frequency differences found in CELEX are often reflected in differences in psycholinguistic experiments, it remains unclear how far findings from this database can be generalized for comparison with spontaneous speech. More specifically, it remains to be investigated whether the syllabic patterns in the spoken language of parents (i.e., infant-directed speech style aka. “motherese”) is similar to the distribution of those patterns in the CELEX lexical database.

In conclusion, the babbling content of young implanted deaf children is very similar to that of NH children in Dutch. Intrasyllabic co-occurrence patterns are the same, with a preference for coronal consonants with front vowels and labial consonants with back vowels. Intersyllabic analysis shows similar variegation patterns as such, with more vowel than consonant variegation and mainly manner variegation for consonants and height variegation for vowels. Yet the variegation in CI children seems to be less complex than in NH children. Fewer combinations of consonant AND vowel variegation are observed with less consonant variegation as a result. Whenever there is consonant variegation, it appears to be preferentially simple variegation (manner OR place) rather than complex (manner AND place).

These data suggest the importance of the production system as well as the importance of perceptual learning from the ambient language. They partially support the FDT for intersyllabic patterns but not for intrasyllabic patterns. Observed consonant variegation is in accordance with the FDT. Preferences for CV co-occurrences seem to be more driven by the ambient language than by the

FDT, although the ambient language does not seem capable to explain all observed data. Importantly, it remains to be investigated whether analyzing genuine child directed speech would help to understand the origin of these patterns better than utilizing data from adult lexical databases such as CELEX for comparison.

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