Prosodic Phonology and Atypical Spoken Language Acquisition in Children who are Hearing Impaired

Jill Titterington

University of Ulster

Abstract
The purpose of this paper is to look at the development of early syllable structure and the minimal prosodic word in the spoken language outputs of two children with hearing impairment who present with additional difficulties in the acquisition of spoken language on top of that expected due to their hearing difficulties. The speech productions of these two children are reviewed using Demuth and Fee's model of syllable structure development (Fee 1997) which was adapted in the light of Kehoe and Stoel-Gammon's (2001) findings.

Child A (male) was aged 9;3 and used a cochlear implant while child B (female) was aged 6;11 and used digital acoustic hearing aids. Aided thresholds were 42 and 45 dBA respectively. Both children were educated in an oral-aural environment although child B’s parents were both Deaf and BSL was their primary language. The model identified the level of each child’s development of English syllable structure and showed very clearly that child B has not yet fully cued in to the basic prosodic properties of spoken English. This method of looking at the syllable structure development of children with hearing impairment could prove extremely helpful in guiding professionals and parents in clinical and educational decision processes.

1 Introduction

Digital acoustic hearing aids and cochlear implants (CIs) have allowed children with severe to profound hearing loss perceptual access to the speech spectrum and opportunities for spoken language acquisition not possible with the traditional acoustic analogue amplification of the past. However, in children with CIs it has become apparent that spoken language outcomes may vary quite extremely (Pisoni 2000). This variability in spoken language outcomes can also be observed in children with hearing impairment who use acoustic hearing aids. While demographic factors can help to explain some of this variability e.g., age of diagnosis, age of amplification etc., a proportion of this variability remains difficult to explain (Pisoni 2000). In recent years, Pisoni and his team in Indiana have shown that capacity and speed of processing in short-term memory are significant underlying contributors to this variation for children with CIs.

Other research has found that alongside memory, our understanding of variations in the acquisition of spoken language in children with CIs can be further developed by looking at the influence of the Prosodic Hierarchy (PH) (Titterington, Henry et al. 2006). The PH is an abstract prosodic structure which determines the syllabification,
stress placement and intonation of an utterance parsed onto it (Selkirk 1995). It stipulates the phonetic and phonological structure of an utterance and assigns metrical foot structure at the level of the syllable (Selkirk 1995). Titterington, Henry et al. (2006) looked at how children with CIs processed weak syllables in the PH that were footed as opposed to unfooted. They found that children with CIs developing spoken language as expected (n=15, mean age = 9:06 (SD = 2:00)) processed both types of weak syllable equally well until memory load increased when they then preferentially processed footed over unfooted weak syllables. A similar but less marked pattern was found for language matched controls indicating that these children with CIs had developed and were using a PH similar to that of their hearing peers with equivalent language levels.

However, a small outlying group of CI users (n= 5, mean age = 10:03 (SD = 2:01)) diagnosed with specific additional difficulties in spoken language acquisition did not process footed or unfooted weak syllables differentially and generally used weak syllables rarely (despite having similar aided hearing thresholds to their CI peers developing spoken language as expected). These children either had not developed or were not using the PH for processing footed or unfooted weak syllables in the same way that their peers with CIs developing spoken language as expected did. This leads to the development of an interesting question about this outlying group of CI users: Can an adapted version of Demuth and Fee’s model of early syllable development (Fee 1997) identify where these children are in relation to their development of the syllable and the minimal prosodic word?

Consequently, this study looked at one child representative of the group of CI users not developing spoken language as expected from the Titterington, Henry et al. (2006) study and a young acoustic hearing aid user who was also not developing spoken language as expected (despite reasonable aided hearing thresholds for both children). The overall aim of the study was to investigate early syllable structure and minimal prosodic word development in the spoken language outputs of these two children.

2 Method

2.1 Design of Study

This single case study uses a non-randomized observational cross-sectional design.

2.2 Participants

Table 1. Demographic Details of participants

<table>
<thead>
<tr>
<th>Demographic details</th>
<th>Child A</th>
<th>Child B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronological Age</td>
<td>9;3</td>
<td>6;11</td>
</tr>
<tr>
<td>Age of Onset of hearing loss</td>
<td>1;2</td>
<td>0</td>
</tr>
<tr>
<td>Age of fitting/switch on of hearing aid device</td>
<td>2;6</td>
<td>0;3</td>
</tr>
<tr>
<td>Age of consistent device/hearing aid use</td>
<td>2;6</td>
<td>3;2</td>
</tr>
<tr>
<td>Aided thresholds</td>
<td>42 dBA</td>
<td>45 dBA</td>
</tr>
<tr>
<td>Receptive language ability (Vocabulary age equivalents)</td>
<td>2;8</td>
<td>1;00</td>
</tr>
<tr>
<td>Mean Length of Utterance</td>
<td>2.7</td>
<td>1</td>
</tr>
<tr>
<td>First Language</td>
<td>Spoken English</td>
<td>British Sign Language</td>
</tr>
</tbody>
</table>
Two children with severe to profound sensorineural hearing loss participated (see table 1 for demographic details). As a similar pattern in variability of spoken language outcomes found for children with hearing impairment who use CIs can be observed in children who use acoustic hearing aids, one child was a cochlear implant user (Child A (male)) and one an acoustic hearing aid user (Child B (female)). Child A was representative of the group of children who were not developing spoken language as expected from the Titterington, Henry et al. (2006) study and Child B was at an earlier stage of language acquisition and also not developing spoken language as expected. Although Child B was being educated in an oral-aural environment (at her parents choice), her first language was British Sign Language (BSL) and her ability to tap into the native prosodic structure of spoken English was of particular interest under these special circumstances.

2.3 Procedure

Speech samples were collected from each child.

For Child A a range of target structures based on Brown’s (1973) grammatical morphemes and the Language Assessment and Remediation of Syntax Profile (LARSP: Crystal, Fletcher et al. 1989) were elicited using modelled elicitation. Thirty two different multiword utterances were targeted and produced through this method.

Child B (who was at the early first words stage of development) was asked to name a collection of objects and pictures of first words. Sixty-four single word utterances were elicited out of a possible one hundred.

For both children, responses were recorded digitally through an omnidirectional microphone (ECN-MS907) using a Sony minidisc recorder (MZ-R700). The speech data was then downloaded into sound wav files in the Cool Edit Programme or Adobe Audition (version 1.5) of a desk top computer using a sampling rate of 32 kHz with 16-bit amplitude quantization. The speech samples were transcribed live voice and then the recordings reviewed by a Speech and Language Therapist specialised in the transcription of speech by children with hearing impairment. As Child B was particularly unintelligible the transcription of her 64 words was validated by a trained phonetician (Dr Christiane Ulbrich).

3 Results

Demuth and Fee’s (Fee 1997) model of syllable structure development was adapted based on Kehoe and Stoel-Gammon’s (2001) findings and used to analyse the speech data in this study. This model is based on the concept of the minimal word where children begin using utterances that are subminimal and do not comply with the minimal bimoraic constraints of spoken English. Utterances gradually evolve to meet word minimality requirements until any prosodic form that occurs in English can be used:

Stage 1:
Core syllable CV – subminimal (monomoraic) e.g., /dɪk/  
Stage 2: Minimal Words (all bimoraic)
- Core syllables (C)V(V)CV(V) (optional stage)
- Vowel length distinctions (C)VV
- Closed syllables (C)V(V)C
Stage 3:
Any prosodic word structure that may be found in English can now be used.
Based on work by Demuth, Culbertson et al. (2006) and Kehoe and Stoel-Gammon (2001) the key questions that were asked of each child’s data were:
1. What syllable structures are used most frequently?
2. How are vowels used?
3. How are codas used?
4. Is there an association between vowel length and coda realization?

3.1 Findings for Child A:

3.1.1 What Syllable Structures are used most frequently?

Figure 1. Most Frequent Syllable Structures Targeted

![Figure 1. Most Frequent Syllable Structures Targeted](chart1.png)

<table>
<thead>
<tr>
<th>Syllable Structure</th>
<th>Frequency Targeted</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVC</td>
<td>18</td>
</tr>
<tr>
<td>CVVC</td>
<td>16</td>
</tr>
<tr>
<td>CVC</td>
<td>14</td>
</tr>
<tr>
<td>CV</td>
<td>12</td>
</tr>
<tr>
<td>CVV</td>
<td>10</td>
</tr>
<tr>
<td>CVCV</td>
<td>8</td>
</tr>
</tbody>
</table>

Figure 2. Most Frequent Syllable Structures Used

![Figure 2. Most Frequent Syllable Structures Used](chart2.png)

<table>
<thead>
<tr>
<th>Syllable Structure</th>
<th>Frequency of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVC</td>
<td>12</td>
</tr>
<tr>
<td>CVVC</td>
<td>10</td>
</tr>
<tr>
<td>CV</td>
<td>8</td>
</tr>
<tr>
<td>CVV</td>
<td>6</td>
</tr>
<tr>
<td>CVCV</td>
<td>4</td>
</tr>
<tr>
<td>CVVC</td>
<td>2</td>
</tr>
</tbody>
</table>
As can be seen from figure 1 the most frequently targeted syllable structures for Child A were CVC, CVVC and CVCVs. Figure 2 shows that while most of Child A’s productions did coincide with the structures most targeted e.g., CVC, he used a range of additional structures to the CVC, CVVC and CVCVs targeted. He used a significant number of open syllabled structures – both with a short (subminimal syllable structure) and long vowel.

3.1.2 How are vowels Used?

As can be seen in figure 3, Child A achieved approximately 75-85% success in his vowel realisations indicating that segmental accuracy of vowels is relatively sound with a clear ability to mark both short and long vowels in his speech productions.

3.1.3 How are Codas Used?

Figure 4 shows that Child A used coda consonants about half the time that they were targeted. He is clearly having some difficulty using coda consonants and rarely realises them accurately.

Figure 3. Vowel Realisations for Mono and Disyllabic Lexical Items
(1 = 1st and 2 = 2nd syllable of the disyllable)
3.1.4 Is there an association between vowel length and coda realisation?

Figure 5 shows that Child A preferred to use coda consonants with lax rather than tense vowels.
3.2 Findings for Child B:

3.2.1 What Syllable Structures are used most Frequently?

Figure 6 shows the most frequent syllable structures targeted from the first words list used to elicit the speech production sample from Child B.

A wide range of structures are targeted but the structures targeted with the highest frequency are the same as those found in the target sample for Child B e.g., CVVC, CVC and CVCVs. Figure 7 shows the most frequent syllable structures used by Child B. Interestingly, Child B did not use any syllable structures that were the same as those targeted. She used a mixture of mono and disyllabic structures –
preferring monosyllables overall. Notably, the syllable structure used most frequently in Child B's speech productions was the subminimal CV structure.

3.2.2 How are Vowels Used?

Figure 8 shows that most of Child B’s vowel realisations are errors. Child B used a range of segmental (some of which were non-English) and vowel length errors e.g., green > /œ/, face > /e/.  

Figure 8. Vowel Realisations for Mono and Disyllabic Lexical Items  
(1 = 1st and 2 = 2nd syllable of the disyllable)

3.2.3 How are Codas Used?

Figure 9 shows that codas were used rarely. Very few of these productions were accurate realisations of the coda targeted.

3.2.4 Is there an association between vowel length and coda realisation?

Figure 10 shows that Child B is realising and omitting codas similarly with lax vowels. However, she does tend to avoid coda consonant use with tense vowels.
Figure 9. Percentage of Coda Consonants Used

Figure 10. Association between vowel length and coda realisation
4 Discussion

In this preliminary study, the four key questions asked of the data for each participant were as follows:

1. What syllable structures are used most frequently?
2. How are vowels used?
3. How are codas used?
4. Is there an association between vowel length and coda realised?

Question 1 addresses whether the participants were able to use English syllable structure reflecting the bimoraic nature of spoken English. Question 2 addresses whether the participants could mark vowel length distinctions. Question 3 addresses whether codas are used by the participants, and if they are used, question 4 addresses whether there is a closer association between the use of codas with lax versus tense vowels. In this context, lax vowels may be seen to license coda use – a process that has been identified as an early stage in the acquisition of coda consonants (Demuth, Culbertson et al. 2006). It appears that it is easier to use coda consonants with lax rather than tense vowels in the first instance.

4.1 Can the participants use English syllable structures?

Clearly, Child A can use bimoraic English syllable structures. However, he does dip in and out of stages 1 and 2 in his use of syllable structure with some continued production of subminimal CV structures. Child B, who is in a signing environment at home, is clearly having difficulty fully cueing in to the bimoraic nature of spoken English.

4.2 Can the participants mark vowel length distinctions?

Child A is producing most targeted vowels correctly and is able to mark vowel length distinctions. In contrast, Child B rarely produces vowels accurately making both segmental and length errors.

4.3 Are codas used by the participants?

Neither participant is using coda consonants frequently or accurately although Child A is managing better than Child B in this context.

4.4 Do coda consonants occur more frequently with lax than tense vowels?

Child A appears to optimally use coda consonants when they are licensed by lax vowels. Child B uses coda consonants rarely. It seems that coda consonants following a lax vowel are easier for her to realise than those following a tense vowel. However, as coda consonants are realised and omitted with similar frequency for lax vowels, it may be a stretch to label this as licensing for child B.

5 Conclusion

It appears that the model of syllable structure development used may be useful when investigating children with hearing impairment who have particular difficulties acquiring spoken language.
Forming an accurate prognosis for spoken language acquisition in children who are severely to profoundly hearing impaired with particular difficulties in spoken language development can be a difficult process. This approach to looking at early syllable structure development may prove to be a helpful part of the future assessment process for such children as the results appear to indicate very clearly if the child has even begun to process spoken language according to its native prosodic properties. In this instance, Child A has begun to tap into the native prosodic qualities of spoken English while Child B is struggling to do so.

Acknowledgements

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References