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Barbara Bernhardt

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# The application of nonlinear phonological theory to intervention with one phonologically disordered child

BARBARA BERNHARDT

School of Audiology and Speech Sciences, University of British Columbia, 5804 Fairview Ave., Vancouver, BC, V6T 1Z3, Canada

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**Abstract**

Speech–language pathologists gain opportunities to search for more effective assessment and intervention methodologies by deriving implications of significant developments within linguistics. This paper describes the application of some tenets of nonlinear phonology to the planning and execution of a phonological intervention programme with one child. The nonlinear analyses provided independent phonological therapy goals for both segmental and syllable structure (prosodic tier structure) development. Higher and lower level features in the feature hierarchy were contrasted in intervention. Prosodic constituents derived from moraic and onset-rime syllable theories were contrasted as facilitators in the attainment of syllable structure goals. A detailed analysis of the changes in the child's speech over two 6-week intervention blocks shows that the goals derived from the nonlinear analyses were logical and attainable. The data demonstrate a faster rate of acquisition for syllable structure (prosodic) goals in the first time block, some predictability for acquisition based on the feature hierarchy, and similarity of effectiveness of the use of different types of prosodic constituent stimuli.

*Keywords*: Nonlinear phonology, disordered phonology, child phonology, intervention.

## Introduction

Application of phonological theory to phonological intervention in the past 20 years has resulted in acceleration of progress in therapy. Describing speech output in terms of coherent phonological systems has enabled clinicians to design intervention programmes which result in generalizations within the system.

Since Goldsmith's (1976) dissertation showing tone as an independently functioning autosegment, new and robust phonological frameworks have become available for utilization, i.e. nonlinear phonological frameworks. When linguists make major changes in the description and explanation of language, speech–language pathologists gain enhanced opportunities for successful intervention by deriving implications of the theoretical changes. In the companion article in this journal some of the developmental implications of nonlinear phonological theory are outlined. In this paper I present a case study example applying and testing some of those implications in terms of phonological intervention (using data from *Subject 1* in the

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Bernhardt [1990] study). The specific questions posed for the study (listed below) related to the concepts of tier autonomy for prosodic and segmental information, types of prosodic theories, and relevance of the feature hierarchy.

1. *Given that phonologists have shown that nonlinear frameworks account for the facts of phonology better than previous theories, will those new frameworks help to predict logical and attainable intervention goals for phonologically disordered children?*
2. *If the autonomy of prosodic and segmental levels of representation of nonlinear phonology is a psychological reality, (a) will intervention be effective if conducted separately for the two levels and (b) will there be a faster rate of change for the dominant prosodic tier?*

If the prosodic and segmental levels of representation are psychologically real, then it should be possible to plan phonological intervention which focuses separately on the two levels, and observe independent development. Furthermore, if the dominance of the prosodic tier over the segmental is developmentally relevant, one might expect to find a faster rate of change for prosodic intervention than for segmental intervention.

3. *Will there be a difference in proportion and rate of syllable/word shapes acquired as a result of interventions that contrast the onset and time versus those that utilize the mora as a constituent?*

Intervention which reflects the most psychologically real representation might be more facilitative, resulting in a faster rate of acquisition of syllable/word types.

4. *If one predicts that higher and, therefore, dominant features/nodes should have developmental precedence over subordinate features/nodes, is there any advantage to be gained from targeting specified features at higher versus lower levels in the feature hierarchy in phonemic inventory intervention?*

The generally agreed-upon organization of the feature hierarchy is such that major class features dominate features of place and voice, and that general place and voice features in term dominate specific details for those parameters. One might predict that higher and, therefore, dominant features/nodes in a hierarchy would have developmental precedence over subordinate features/nodes.

## Method: Part I—Subject characteristics and assessment analysis

### *Subject characteristics*

In order to illustrate the application of nonlinear phonology in intervention I have chosen the subject with the least complicated phonological system from Bernhardt (1990). This boy, aged 5;10–6;3 during the period reported here, was very talkative in spite of reduced intelligibility. In fact, his volubility (and often rapid rate of speech) contributed to reduced intelligibility. Table 1 shows characteristics of the subject. His phonological disorder was associated with:

Table 1. *Subject information*

| | |
|---|---|
| Age, gender | 5;10–6;2, male |
| Birth order | Second of three boys; third has mild phonological disorder |
| Dialect | Mother—English; Father—Australian; Residence—Vancouver, Canada (previously Vancouver and Australia) |
| Hearing, language skills | Normal limits |
| Phonemic discrimination | Test of Language Development (Primary) (Newcomer and Hammill, 1982): Auditory Discrimination Subtest—borderline average (*S.S.* of 7)<br>Goldman–Fristoe–Woodcock Auditory Discrimination Battery (Goldman, Fristoe and Woodcock, 1974): $-1{\cdot}5$ *S.D.* |
| Oral mechanism | Tongue thrust during speech and swallowing<br>Class 1 malocclusion<br>Finger-sucking habit<br>Some lack of independence for jaw and tongue movements, such that elevation of the tip and body of the tongue could not be performed with an open jaw before training |
| Previous therapy | Between 2;9 and 5;0, intermittent therapy for final consonants, /f/ and /t/ with other speech-language pathologists in Vancouver and Australia<br>A few sessions in the 4 months prior to the project with a school speech-language pathologist (introduction of /ð/ and /l/ at word level)<br>No changes in conversational speech noted in the year prior to the study |

1. oral mechanism factors: A 'tongue thrust' during speech and swallowing, finger-sucking, and a mild open bite;
2. mild difficulty with phonemic discrimination;
3. dialectal variation in input by changing residency—Vancouver (3 years), Australia (2 years), Vancouver (1 year)—and parent's dialect—mother English, father Australian;
4. family position as the middle child of three boys (the younger sibling having a mild articulation disorder).

### *Phonological sampling procedures*

A set of 164 objects and pictures provided stimuli for a (predominantly) spontaneous single-word assessment elicitation, which was recorded using a Nagra IV reel-to-reel tape recorder and Ampex 631 tapes with an AGK D202 microphone. General conversation during the recording session provided another 117 words for analysis, many in connected speech contexts. The 164-word list probed all English consonants in word-initial position (WI), word-final position (WF), syllable-initial-within-word position (SIWW) and, where possible, syllable-final-within-word position (SFWW).† In order to check for morphophonemic effects on WF consonants (becoming SIWW

† The word position categories follow Grunwell's categories (1985), although SIWI and SFWF are denoted as WI (word-initial) and WF (word-final) respectively. SIWW (syllable-initial-within-word) and SFWW (syllable-final-within-word) are the same as in Grunwell *[1985]*.

after derivation), derived forms were also elicited, through adjunction of [i] to nouns and [ɪŋ] to verbs, e.g. *sun, sunny; rub, rubbing*. In order to control for possible assimilatory effects, consonants were elicited in a variety of word shapes which included CV, VC, and $C_iVC_i$ words (when such words existed) as well as more complex word shapes. Vowels and diphthongs were not specifically probed, but all were available for analysis.

### *Phonetic transcription*

The experimenter (*E*) performed narrow transcriptions of the assessment and major probes using a Revox taperecorder, Videoconcepts F700 dynamic earphones, and IPA (1979) symbols and diacritics. Each item was coded for type in terms of context (single word versus connected speech) and spontaneity (spontaneous, echoic, delayed echoic, delayed self-echoic, and whether prompted or unprompted).

Seventy words from the beginning of Block 1 and Block 2 major probe tapes (yielding 138 consonants in total) provided a database for determining intertranscriber reliability. A second individual transcribed the taped samples independently. To calculate reliability, each phonetic slot with its onset or offset characteristics counted as one item. For example, *E* may have transcribed a child's production of /tɔɪ/ as [tʰɔɪ]. The second transcriber may have transcribed that same item as [tɔᵊ]. In this case the consonant difference counted as one mismatch (aspirated versus unaspirated) and the diphthong difference a second, yielding zero matches for the word (0/2). When transcriptions did not match, the two listened jointly to the tape in order to resolve disputed forms. For the subject (*S*), the two transcribers were in agreement for about 75% of the consonants prior to discussion, and 97% after discussion. Disagreements primarily concerned degree of dentalization of the coronal obstruents (i.e. dental versus interdental), and degree of voicing (unaspirated versus voiced). Neither of these disagreements affected the intervention outcomes.

### *Phonological system at the time of assessment*

In concordance with the concept of tier autonomy, separate prosodic and segmental level analyses of *S*'s sound system were performed. Data were first organized in charts (exemplified in Tables 2 and 3) which provided details of syllable/word structure and segmental realizations. These databases were then interpreted in terms of nonlinear phonological frameworks and hypotheses.

### *Prosodic tier: Syllable and word shapes*

*S*'s word structures (i.e. CV constituency, not segmental realizations) matched the adult targets in terms of number of syllables/word, number of final consonants/word, and diphthongs.

The sole mismatch in terms of word/syllable structure occurred for syllable-initial consonant clusters, 69% of which were reduced or simplified in comparison with the adult target. As the length of the word increased, the frequency of reduction increased. The following was observed in terms of cluster matches for '*skeletal slots*' (i.e. CC, not actual segments):

Table 2. *Sample of assessment cluster onset data*

| Adult targets | | Child forms | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Morpheme level | Phonetic level | CVC | CVCV | CCV | CCVV | cCVC[a] | CCVC | CcVC | CCV.CV |
| | CCV | | | 1 | | | | | |
| | CCVV | | | | 1 | | | | |
| | CCVC | 10 | | | | 1 | 5 | 1 | |
| CCVC+V | CCV.CV | | 1 | | | | | | |
| | CCVVC | | | | | | | | |
| | CCV.CVr | | | | | | | | 1 |
| | CCCVC | | | | | | 2 | | |
| SUM | | 10 | 1 | 1 | 1 | 1 | 7 | 1 | 1 |

[a]cC = fricative with stop onset; Cc = stop with fricative or glide following.

Table 3. *Sample segmental datasheet for singletons and clusters*

| Seg/ Clus | WI % Match | WI Match No. | WI Non-match | WI Feature differences Type | WI Feature differences Tokens | SIWW % Match | SIWW Match No. | SIWW Non-match | SIWW Feature differences Type | SIWW Feature differences Tokens |
|---|---|---|---|---|---|---|---|---|---|---|
| t | 12·50 | 2 | 14 | *R: cont s* | 1 | 43·75 | 7 | 9 | *LN: voice s* | 3 |
| | | | | *RN: comp s* | 5 | | | | *Cor: dstr s* | 9 |
| | | | | LN: sp gl u | 12 | | | | | |
| | | | | *Cor: dstr s* | 10 | | | | | |
| tw | 0·00 | 0 | 8 | C1: RN: ∅ | 6 | | | | | |
| | | | | *C1: RN: cont s* | 2 | | | | | |
| | | | | *C1: Lab s/Cor* | 2 | | | | | |
| | | | | C2: Correct | 3 | | | | | |

Note: Italics designate inappropriate specification in terms of the adult model. WI = word-initial; SIWW = syllable-initial-within-word; RN = Root node; LN = laryngeal node; sp gl = spread glottis; cont = continuant; dstr = distributed; Cor = Coronal; Lab = Labial; u = unspecified.

1. WI diconsonantal clusters, monosyllabic words: 11/26 (42·31%) matches;
2. WI diconsonantal clusters, disyllabic words: 8/26 (30·77%) matches;
3. syllable-initial within word (SIWW) disconsonantal clusters: 1/7 possible matches;
4. WI diconsonantal clusters in four-syllable words and triconsonantal clusters: no matches.

*Syllable position realization for segments*

In terms of mapping between the prosodic and segmental tiers, further constraints were observed for clusters. Even if two consonants were present, only one word with a /gj/ cluster (*argue*) had matches for *both* segments. In general, the first segment of the cluster matched the adult target 37·31% of the time and the second element 24·14% of the time.

Type of segment also affected realization of the two consonantal-type elements, as is demonstrated below for /s/-clusters and stop/approximant clusters. Syllable-initial disconsonantal structure was partially established (31%) in terms of the prosodic level, but realization of the structure depended on segmental constraints, suggesting a bidirectional influence between prosodic and segmental tiers, mediated at the skeletal tier level (see Table 4).

*/s/-Clusters*

The second element of the /s/-cluster affected degree of skeletal slot realization.

(1) Missing segments in diconsonantal /s/-clusters appeared for: /s/-stop and /s/-nasal clusters (two of three possible /sn/ tokens), i.e. where the second element was a non-continuant consonant. Given two segments and a structural constraint against two elements, the more likely one to appear could be (1) the better-established segment, or (2) the one which can be immediately syllabified, i.e. the one that is not '*extrametrical*' (as defined by notions of sonority hierarchy in Kiparsky, 1979).

In /s/-stop clusters the least sonorous element, the stop, is syllabified (CV) and the /s/ is then considered extrametrical. In terms of developmental phonology the stop will thus remain given a CV structure, and the /s/ will be sacrificed. The notion of extrametricality accounts for the failure of /s/ to appear in *S*'s realizations of /sp/ as [p] and /sk/ as [k]. However, it does not appear to account for /st/ realizations. The /st/ did not pattern with the other /s/-stop clusters but was produced as [θ], *S*'s default coronal continuant (see segmental data below). As singletons, /t/ and /s/ were not completely contrastive, a factor which possibly affected the syllabification potential of /t/. WI /t/ was realized 6/16 times with continuancy (once as [θ] and the rest of the time as an affricate [ᵗθ]). WI /s/ was realized 1/10 times as a stop, 10/10 times interdentally, and 2/10 times as [ᵗθ]. For the /st/-cluster, the segment with more specified features, i.e. /s/ by virtue of its consistent [+continuant] specification, was realized.

The realization of /sm/ and /sn/ (two out of three tokens) was similar to that of /sp/ and /sk/ clusters, in that the /s/ was missing. The extrametricality hypothesis would not predict this outcome, because the /s/, as the less sonorous of the two syllabifiable elements, should then be realized. However, the fact that nasals were better-established as a sound class, i.e. a segmental factor, may have overridden any

Table 4. *Syllable-initial clusters at initial assessment and at the end of Block 1*

| Cluster | Assessment | End of Block 1[a] |
|---|---|---|
| (/sn/)[b] | Pros[c]: (CC) (1/3)<br>Seg: /s/ > [+ *distributed*][d] | Pros: /sn/ > CC† <br>Seg: /s/ > [+ *distributed*] |
| /sp, sm, sk, (sn)/ | Pros: C<br>Seg: /s/ RN[e] > ∅ | Pros: CC†<br>Seg: /s/ > [+ *distributed*] |
| /st/ | Pros: C<br>Seg: /s/ > [+ *distributed*]; /t/ RN > ∅ | No change |
| /Cl/: | Pros: C<br>Seg: /l/ RN > ∅[f] | Pros: CC†; epen. (1/2)<br>Seg: /s/ RN > ∅ (1/2); /l/ > [j] or [lj] |
| /Cj/ | Pros: C<br>Seg: /j/ RN > ∅ (except SIWW [gj]) | Pros: CC* except /mju./;<br>Seg: Match except /mju./ > /my/ |
| /C/[w] | Pros: CC or (C)[g]<br>Seg: $C_1$ matches: When Labial or after epenthesis vowel<br>Usually $C_1$ Labial [+ cont], i.e. [f] | Pros: CC*,†<br>Seg: $C_1$: Matches except for most coronals<br>$C_2$ remains [w] |
| /sCC/ | Pros: C or CC<br>Seg: Labial [f] or [fw] | Pros: C(C)† (Epen.)<br>Seg: Variable |

[a]Summary of major and minor probe data—highlights only. Changes are represented with asterisks (*) for trained targets and dagger (†) for untrained targets.
[b]Marginal acquisitions noted with parentheses.
[c]Pros = prosodic tier information; Seg = segmental tier information.
[d]*Italics* = inappropriate specification according to Appendix Feature Specifications.
[e]RN = Root node.
[f]One instance of [j] for /l/.
[g]19/32 with CC, otherwise C.

syllabification tendencies, a hypothesis which accounted for the realization of the /st/-cluster, and could also account for /sp/ and /sk/ realizations as stops. That the extrametricality hypothesis still had a role to play in development of clusters is seen below, however.

(2) Clusters with two segments realized: /sn/ once (*snake* > [θn:ɛɪk]), and [fw], from /s/-clusters with [w] as a second element (from /w/ or /l/ in /s/C-clusters, or /r/ in /s/CC clusters). The [fw] substitution matches realization of stop clusters with [w] (see the section on stop-clusters below), and once again affirms that syllable structure realization depends partially on segmental composition. Both the [fw] and the single token of [θn] also support the extrametricality hypothesis. If the second element of a cluster is more sonorous than the first, both can have a surface realization, because syllabification will take place on the least sonorous element.

### *Stop-initial clusters*

Stop-glide clusters (phonemic or phonetic glides, e.g. /w/ as an underlying glide or [w] as a 'substitution') behaved similarly depending on the glide involved (see Table 4).

(1) Clusters with one element produced: stop-/l/, stop-/j/, and 10/32 stop-[w] clusters. Neither /j/† nor [j] from /l/ appeared for /Cj/-clusters, except once in SIWW position after /g/ (*argue*>[ɑugju]). (The apparent anomaly of /sl/ patterning with the [w] clusters, i.e. /sl/>[fw], in this context is within the general sound patterns of the system, since there were two tokens of [w] for /l/ in the singleton data).

As noted, occasionally only the first element appeared for stop-[w] clusters, e.g., for WI /br/, /fr/, /θr/, /kw/, and /tw/. This is consistent with predictions of the sonority hierarchy hypothesis (Kiparsky, 1979) that the least sonorous element will be realized. However, in the case of the disyllabic items *twenty* and *quiet*, alternatives were [fw] or [w]. The [w] production appears to violate the sonority hierarchy hypothesis, but is consistent with /s/-nasal cluster realization noted previously. In the case of /tw/ and /kw/ the /w/ is phonemic rather than phonetic, which may have had some bearing on its realization. Furthermore, it may have been a *better-established* segment than the stops (see note above under the section on /st/-clusters), and thus a more likely candidate for realization.

(2) Clusters with two elements produced: [w] as the second element (22/32). The appearance of obstruent-[w] clusters is consistent with the sonority hierarchy hypothesis as relevant for realization of two elements. The stop produced matched its target only if that target was labial (e.g. *bread*>[bwʌdᵊ]), or in single word utterances where vowel epenthesis appeared (e.g., *grey*>[gəwɛɪʲᵊ]). When there was no epenthesis, and *always* in connected speech, spreading of specified (Labial Place) and unspecified ([+continuant]) features of [w] resulted in [fw] substitutions for clusters, even for one with a labial initial consonant (e.g. *truck*>[fwʌk]; *brush*>[vwʌθ]).

### *Segmental development and feature hierarchy*

No significant discrepancies were noted for the vowel system. Hence, only consonant data are reported.

Across all consonants and cluster segments, 39·96% of the child forms matched adult targets. Table 5 shows established and unestablished segments by sound class (an independent analysis), as well as feature differences for unestablished segments (a relational analysis). Figure 1 demonstrates the hypothesized feature geometry for *S* at time of assessment, as inferred from the spreadsheet database and segment/feature relationships outlined in Appendix 1.

'Established' categories of the segmental system (at least 80% matches with the adult model) represented in Table 5 and Figure 1 were:

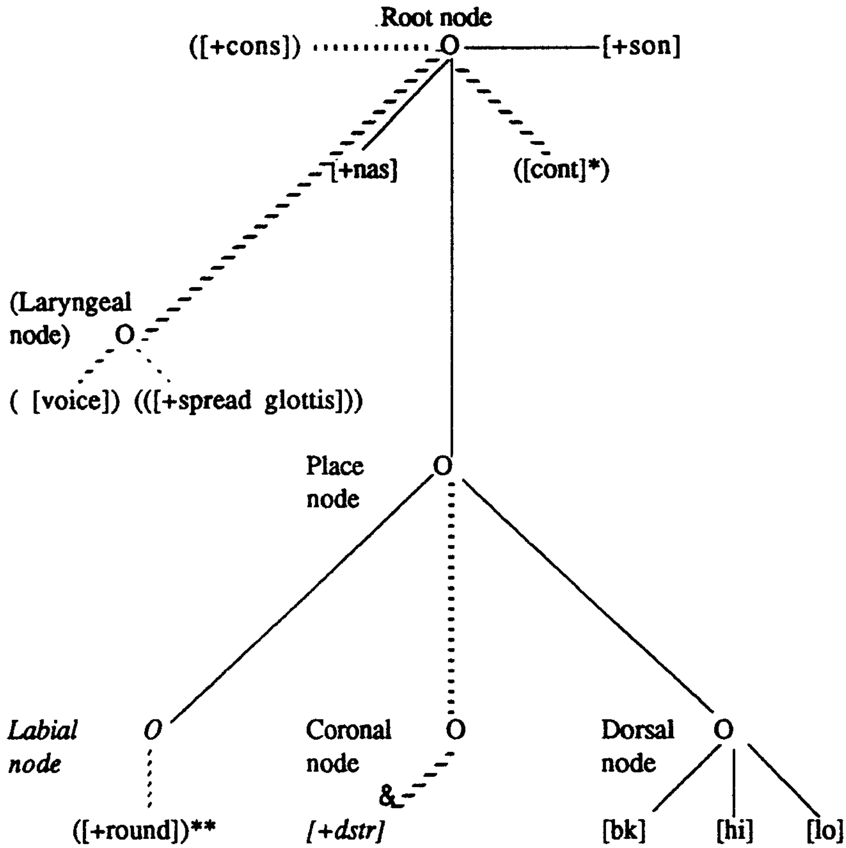
1. Nasals and glides,
2. Labial and Dorsal Place stops (except WI),
3. Labial Place fricatives.

† The sequence /CjV/ was considered a cluster followed by a vowel, although some linguists consider the sequence to be a consonant followed by a light diphthong. *S*'s singleton substitution for /l/ was [j]. Both /ClV/ and /CjV/ sequences were realized with missing /l/ or /j/. It seemed more appropriate to consider the /j/ a 'consonant' than to consider /l/ a vowel in the particular context. This decision permitted consistency of /l/ specification as [+consonantal], the higher level feature being contrasted with lower level [−anterior] in the Block 1 and Block 2 feature conditions.

Table 5. *Summary of singleton consonant acquisition at assessment*

| Sound class | Established segments[a] | Unestablished segments[a] | Main feature differences |
|---|---|---|---|
| Glides—/w, j/ | All | | |
| Nasals | All | | |
| Stops [ – voice] | All: WF, SFWW<br>/p/, /k/: SIWW<br>(/t/: SIWW—43·8% [7/16])[b] | /p/: WI—0% (0/10)<br>/t/: WI—12·5% (2/16)<br>/k/: WI—27·3% (3/11) | WI: LN: [+spread glottis] u[c]<br>/t/: RN: '*complex*' *s<br>Cor: [+*distrib*] *s |
| Stops [+voice] | /b/, /g/: All<br>(/d/: WI—50% (6/12); WF—42·9% [3/7]) | /d/: SIWW—33·3% (1/3) | /d/: Cor: [=*distrib*] *s |
| Fricatives—Labial Place | /f/: All<br>/v/: WI, SIWW<br>(/v/: WF—67% [2/3]) | | Root node: [+cont] u once for /v/ |
| Fric/Affricates—Coronal Place | /θ/: SFWW—2/2<br>(/ð/: WI—72.7% [8/11])<br>(/ð/: WI, SIWW—50% [1/2; 1/2]) | /ð/: SIWW—25% (1/4)<br>/θ/: WF-33·3% (1/3)<br>All others | Cor: [+*disturb*] *s for most (but u for /θ/, /ð/), [–ant] u for alveopalatals<br>RN: 'complex' *s or u, (i.e. inconsistent) |
| /h/ | Neither word position | Both word positions | Root node: [+cont] u |
| Liquids—/l/, /r/ | Neither | Both | Both: [+cons] u[d]<br>/r/: *Labial* Place *s* in place of Coronal* |

[a]Established = 80% matches or better; partially established segments (40–80% matches) are shown with parentheses in the 'established' column. Unestablished = 0–39%. (These are arbitrary cutoffs.)
[b]WI = word-initial, WF = word-final, SIWW = syllable-initial within-word, SFWW = syllable-final within-word.
[c]u = unspecified according to a model of radical underspecification; *italics*, *s = '*specified*' inappropriately with reference to Appendix Feature Specifications for adult English.
[d]WI /l/ > [lj] 1/5 times echoically, i.e. [+cons] specified, but secondary palatalization present.




Note: Parentheses indicate partially-established features in system development. Italics indicate inappropriately specified feature, e.g., labial place for voiceless interdental and /r/. Dotted lines indicate partial establishment.
*'Complex' branching structure inconsistently applied.
**[ʊ] not [+rd]
&[+dstr] = default interdental tongue place.

Figure 1. *Feature geometry at initial assessment.*

In terms of the feature hierarchy, then, the following specified features were established:

1. Root node: [+nasal] and [+continuant],
2. Laryngeal Node [+voice],
3. Labial and Dorsal Place nodes.

Coronal Place node was partially established for obstruents (more so word-finally). For partially established segments (/t/, /d/, /θ/, /ð/) there was some overlap between the stops and fricatives (except for /θ/), indicating a lack of clear specification for

[+continuant]. (Once /v/>[b], showing that [+continuant] was still not completely established, even for Labial Place fricatives.†)

By syllable position (i.e. syllable-segment mapping), syllable-final (SF) position was advanced over WI position, which in fact had the fewest matches overall (30·33%).

Unestablished sound classes (or phoneme groups) were:

1. liquids: /l/>[j] or occasionally, [w]; /r/>[w];
2. non-distributed coronal fricatives/affricates (sibilants>[θ] or [ᵗθ], or voiced counterparts);
3. /h/>[ʔ];
4. aspirated voiceless WI stops.

Feature differences between the adult target system and *S*'s system are discussed below.

### *Summary of feature differences between the adult system and* S*'s system*

The following represented the most salient of the feature differences (descending order) and are expressed in terms of the feature hierarchy and underspecification. (Reference to Appendix 1 and Bernhardt's companion article in this journal will assist the reader in understanding the differences.)

### *Child forms as yet unspecified where adult targets are specified*

Children are expected to add marked features of the language as they progress. The following marked features were either partially established or unestablished for the subject at assessment.

1. Root node: [+consonantal] unspecified for liquids except 1/35 times for /l/, but specified for other consonant classes;
2. Root node: [+continuant] unspecified for /h/ but specified for Place nodes;
3. Root node: 'complex' structure of coronal SI affricates versus non-complex structure of coronal stops and fricatives not consistently specified or unspecified;
4. Laryngeal node: [+spread glottis] redundant feature not specified for 32/37 WI [-voice] stops.

### *'Specified' child forms where adult targets are unspecified or otherwise specified*

As discussed in Bernhardt's companion article in this journal (in the section on underspecification), children do not always appear to have the unmarked feature of the adult language as their default feature, because of early or continuing perceptual or motor immaturity. In these cases they may appear to be using a specified feature

† Between ages 3 and 4 years in Australia, *S* received therapy for /f/, which he produced as a stop (no information as to which stop).

of the adult language, or a feature which does not appear at all in the adult language. The child's '*specified*' feature has a default quality as a typical and systematic substitution. Adult-like specification has yet to occur. For this subject the major defaults were as follows:

1. Place node—Coronal Place: the [+*distributed*] interdental or dental place was a feature of sibilants and some coronal stops. This descibes the interdental tongue position. The 'default' coronal segment for *S* was not [+anterior] but [+*distributed*].
2. Place node: *Labial* for Coronal Place node appeared for realizations of /r/, a few tokens of /θ/, and stops in clusters with stops and [w].
3. Root node: [+*continuant*] appeared as a feature of the first element of clusters with [w]. This feature difference and the one above were concurrent ([fw]) and facilitated the appearance of two-element clusters, as discussed above.
4. Coronal fricatives and stops had '*complex*' branching structure in WI position 9/41 times.

## Method: Part II—General experimental design and specific intervention plan for the subject

As an outcome of the assessment, *E* set up goals for intervention, organized sequentially according to the experimental conditions for the subject.

Because phonologists have shown over the past 15 years that nonlinear frameworks account better for the facts of phonology than previous frameworks, the current study took that as a starting assumption. Hence, this study did not compare nonlinear analyses with the many available types of phonological rule or process procedures (e.g. Edwards and Bernhardt, 1973; Ingram, 1981; Hodson and Paden, 1983; Grunwell, 1985; Elbert and Gierut, 1986, etc.), but asked whether, independently, the frameworks would capture facts of the child's (disordered) phonology in a way that would suggest logical and attainable goals for intervention.

The experimental design incorporated both a multiple baseline and an alternating treatment format. Untrained phonological targets served as baselines against which to compare trained targets. It was predicted that (1) trained targets would show the greatest improvement, and (2) those phonological elements similar to trained targets, either in feature components (with reference to segmental intervention) or prosodic slots (with reference to prosodic intervention), would show most improvement through generalization.

The alternating treatment design allowing contrasting of condition types relating to the last three research questions outlined in the introduction: (1) intervention targeted at the segmental versus prosodic tier (main conditions), (2) prosodic stimuli presentation and production manipulations as moraic versus onset-rime constituents (prosodic tier sub-block conditions), and (3) training of higher level versus lower level features in the feature hierarchy (segmental sub-block conditions).

The alternations occurred over two 6-week sequential blocks, with three 45-minute sessions per week. More specifically, the alternations took place: (1) every nine sessions (i.e. approximately every 3 weeks) for each of the segmental and prosodic level training sub-blocks, and (2) every four sessions (i.e. approximately every 10 days) for the within-sub-block conditions (feature hierarchy contrast and prosodic theory contrast). The alternation periods were considered long enough to allow learning within each condition, but short enough to be considered alternating. The design allowed for a minimum of two alternations for each condition across the time blocks, a minimum recommended for such designs (Barlow, Hayes and Nelson, 1984, p. 229). (Counterbalancing of condition orders was carried out over all subjects in the Bernhardt, 1990, study, rather than within subjects.) The design for *S* is schematized in Figure 2.

### *Target selection for S*

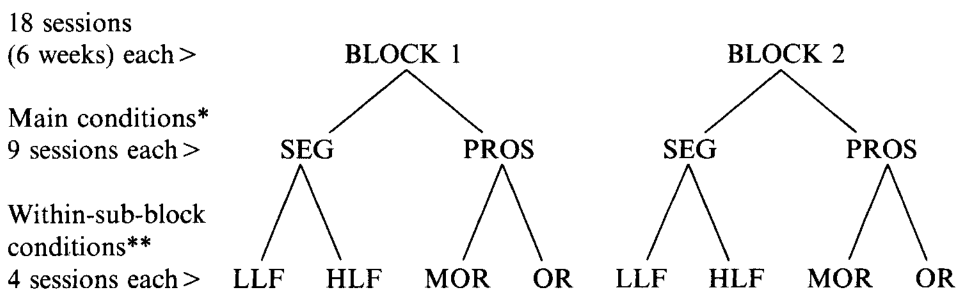
As Figure 2 shows, in *S*'s first sub-block, segmental goals were targeted—first lower, then higher level feature targets. The second sub-block, for prosodic tier goals, followed the order moraic, then onset-rime stimuli presentation. Specific targets and rationales are presented below.

### *Segmental tier condition*

*General assumptions for target selection*

The fourth research question of the study related to possible differential rate of acquisition for higher versus lower features in the feature hierarchy. Unestablished or very marginally established features (less than 10% matches) were considered possible training targets. Since the phonological theory of radical underspecification predicts that the unmarked value for a feature is its default value (the universally endowed value) and, by consequence, the marked value is the one that needs to be 'learned', the marked value of a feature was the training target. The following general assumptions, with respect to classification of feature height and relationship to segments, underlie the specific rationales for selection of targets for *S* and hence are presented here in detail:

1. Terminal features are lower than intermediate nodes or other non-terminal nodes, i.e. the terminal feature [round] is lower than its class node—Labial Place.




*SEG = segmental tier condition; PROS = prosodic tier condition; 1 session = minor probe
**MOR = moraic; OR = onset-rime; HLF = higher level feature; LLF = lower level feature

Figure 2. *Schematization of research design.*

2. Terminal features of a node are equivalent in height, i.e. Coronal Place feature [+distributed] is at the same level as Coronal Place feature [−anterior].
3. Root node features are at the highest level, with [+consonantal] and [+sonorant] higher than terminal features [+nasal] and [+continuant].
4. Laryngeal node features are lower than Root node features but higher than Place node features. Although the theory does not assume that Place node is lower than Laryngeal node, *E* assumed that glottal functions take precedence over shaping of the oral cavity.
5. Place node is higher than Labial Place and Dorsal Place nodes, which are at the same level.
6. Coronal Place node was considered 'higher' than Labial Place and Dorsal Place nodes, by virtue of its default Place node status. Since a default feature is assumed unless other specification is made, this primary status of defaults was considered to place them higher in the hierarchy than comparable features or nodes.
7. In order to select segments for which the chosen features were targets, *E* assumed the segment/feature relationships appearing in Appendix 1. Since establishment of features was the goal, more than one segment was a possible training target during a feature sub-block, with some segments for which that feature was distinctive remaining as baseline observation targets.
8. The prosodic tier data dictated choice of word position for target training. Only well-established word positions served as slots into which to insert the new segments, in order to maintain as much independence as possible between the segmental and prosodic tier conditions. For this subject, words without syllable-initial clusters were possible training items.

*Segmental tier targets*

1. Lower level feature: Coronal node [−anterior]
   training segments: /ʃ/ and /ʤ/ (all word positions),
   untrained observation segments (multiple baselines with the same feature): /ʧ/ and /ʒ/.

*Rationale.* By establishing alveopalatals, the coronal place node would be specified with one of its marked features—[−anterior]. Specification of this lower level feature would limit the distribution of the child's 'default' coronal feature—[+*distributed*]. By using one voiceless fricative and one voiced affricate in training, distinctions between complex/non-complex, and voiced/unvoiced segments, could be made more salient. Generalization of [−anterior] could be observed by probe testing of untrained related segments /ʧ/ and /ʒ/.

2. Higher level feature: [+consonantal] in conjunction with [+sonorant]
   Training segment: /l/ (WI and SIWW positions),
   Untrained observation segment (multiple baseline with same higher level feature): /r/.

*Rationale.* Assuming that /l/ requires specification of Root node feature [+consonantal] in conjunction with [+sonorant], /l/ has a higher level feature target than the alveopalatals. (Even if a feature [+lateral] had been invoked for /l/, that feature would have been higher than [−anterior], because the locus of a [+lateral] feature would have been the Place node itself, i.e. 'above' Coronal, or the Root node). The syllable-initial positions were targeted, because of a reasonable degree of stimulability and because of the parents' dialect, in which the postvocalic /l/ is barely audible. *E* selected /l/ rather than /r/ for liquid establishment because /l/ was slightly more phonetically stimulable than /r/† at the time. Thus /r/ remained a related observation target.

Because /r/ had more distinctive features than /l/ (other than [+cons]), generalization to /r/ from /l/ seemed less likely than generalization among the alveopalatals above.

3. Other untrained observation targets
   (a) Coronal stops and fricatives: observation of use of [+distributed] default, and complex/non-complex branching structure. Since all targets in the segmental sub-block were coronal, generalization could be expected.
   (b) /h/ and aspirated voiceless WI stops: minimal change for /h/ or the WI stops was expected after segmental sub-block training, since [+continuant] and [+spread glottis] were not specific target features.‡

*Prosodic tier condition*

The main goal was realization of two skeletal slots (CC) for diconsonantal WI clusters. In order to maintain as much independence as possible between the segmental and prosodic tier conditions, only well-established segments were used as stimuli within those clusters. Because all other clusters contained unestablished segments, only /w/- and /j/-clusters were available as intervention targets.

*Prosodic tier targets*

1. Moraic sub-block§
   Targets: syllable-initial clusters /kw/, /kj/, /pj/.
2. Onset-rime sub-block
   Targets: syllable-initial clusters /tw/, /fj/, /vj/, /mj/.
3. Observation targets.
   All other syllable-initial clusters, both with respect to the main goal of realization of two cluster slots, and with respect to segmental realization of these cluster slots.

*Rationale for cluster selection*

The onset-rime condition had one more /j/-cluster target than the moraic condition, because of limitation in available lexical items for /fj/- and /vj/-clusters. This

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† *S* could not imitate the segmental targets accurately as single phones or in syllables at the onset of intervention (/l/ > [lj]; /ʃ/ > ungrooved, low tongue position).

‡ Because *S*'s mother did not use /h/ consistently in her dialect, /h/ was not considered an appropriate intervention target, but rather an observation target unrelated to the intervention targets.

§ *S* could not imitate normal rate target syllables of moraic or onset-rime conditions at the onset of intervention (CC > C).

inequality may have been advantageous to the onset-rime conditions in terms of generalization potential. However, the inherent difficulty of onset-rime target /tw/ (with the underspecified and problematic WI /t/) was considered an inequality favouring the moraic condition.

### *Treatment methodology specific to the prosodic condition*

General treatment session methodology is presented in Appendix 2.† Because the difference between the moraic and onset-rime conditions was primarily emphasized through presentation of alternative types of stimuli to be imitated, this specific methodology is presented here. (Once *S* demonstrated phonetic control of the syllable/word structure target, procedures for establishing phrases and sentences were the same as for segmental targets, i.e. as outlined in Appendix 2.)

### *Stimuli presentation*

In terms of contrasting onset-rime and moraic stimuli, *constituent status* was considered the distinguishing variable. Thus, '*CC*', if presented separately, was a constituent—a domain with internal structure and its own set of operations. Because onset clusters do not form constituents in moraic theory, *E* did not present them as such in the moraic condition. Furthermore, presentation of a (moraic) CV unit does not focus on the onset and rime as separate and independent constituents, the desired objective for the onset-rime condition.‡

At the outset of imitation training during moraic and onset-rime sub-blocks, *E* presented segments, syllables and/or words through speech while providing simultaneous visual and physical manipulation cues. These cues were provided in such a way as to emphasize phonological constituent according to the theory in question.

In onset-rime theory the onset and rime are considered separate constituents. Thus, in the onset-rime condition the maximal onset and maximal rime of a word were presented as an alternating set of discrete stimuli. For example, *E* presented a CCVC word (such as *tweak*) as CC and VC ([tw:]-PAUSE-[ik]), repeating the constituents alternately several times at increasing rates. At the same time, *E* pointed to letter groups or moved blocks with 'tw' and 'eak' printed on them over each other. The child copied the procedures. In this case prolongation of the glide /w/ or /j/ initially created a new O-R unit—[tu], which would then be reduced in duration as rate increased.

In moraic theory the prevocalic consonants are not considered a viable constituent, but rather, separate elements adjoined to the mora or syllable node. In order to focus on the separateness of the two prevocalic elements, the outermost consonant

† Throughout the study, training words had only one mismatch with the adult word—the feature/segment or cluster to be trained in that sub-block. For example, when /l/ was a target, the word *luck* was a possible training word, since /k/ > [k], but *lose* was not, since /z/ > [ð].

‡ One could argue that the two types of stimuli overlapped to a certain extent. In terms of the onset-rime (O-R) stimulus presentation, the O-R units (C)C and V also demonstrate separation of the moraic unit—V—from the prevocalic consonant(s). One could furthermore construe the CV moraic stimulus as an O-R (CV) combination. However, as stated, constituent status was considered the distinguishing variable, and segments presented together were considered to be unitary structural constituents with their own set of functions.

was presented separately from the innermost, the latter being considered already 'attached' to the vowel (the child's core syllable CV). Thus the outermost consonants was added to the CV unit. For example, a CCVC word was presented as a C and a CVC, i.e. [k]-PAUSE-[wɪt] (again repeated alternately several times while pointing to the individual letter and the groups, or moving blocks over each other with 'k' and 'wit' printed on them). In this way the 'onset' was never presented as a constituent during the moraic condition.

It might seem that pronounceability of C-CV versus CC-V might have benefited the moraic condition from the outset. For CC-V a phonetically motivated glottal onset to VC (CC-ʔV) would have to be suppressed in order to form a word from the constituents presented in the onset-rime condition. However, by gradually increasing speed of pronunciation, the [ʔ] was suppressed.

Possible advantages for onset-rime condition training, on the other hand, may have arisen through (1) contrast training heightening awareness of onsets such as [st] versus [t] versus [s], and (2) rhyming activities heightening awareness of the rime.†

### *Probe testing during the study*

Three evaluative probes were administered per block, at sessions 9, 18, and 19. The *minor* probes at sessions 9 and 18 were tests of specific segmental or prosodic tier targets from the previous 3-week condition. The probe words for the minor probes were different from those used in therapy sessions, and were primarily elicited as spontaneous single words (unless a word was not known, in which case imitation was used, or unless the child spontaneously used the word in a phrase or sentence). *E* also collected a story retell sample which focused on the targets in question (using either Clinical Probes of Articulation Consistency [Secord 1981] stories or concocted ones) and a conversational speech sample. They were recorded on Fuji FR-II cassettes using a Marantz PMD220 tape recorder and AKG D310 microphone.

The major block probe, recorded on reel-to-reel equipment at session 19 following a 1-week therapy break, consisted of the standard 164-word list used for the assessment (again the words of which were not used in treatment sessions), plus any conversational speech elicited.

If probes revealed that goals were met (match data of approximately 70% in conversation), new goals were derived. Otherwise, the first set of goals continued for the next block.

Following the study, probe results were used to compare condition outcomes. Treatment session tapes were also used for *post hoc* analysis, specifically with respect to the third question on moraic versus onset-rime stimuli presentation.

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† If psychologically real, the notion of extrametricality may have created other biases. In both theories, the /s/ may be considered extrametrical when preceding a stop word initially (Kiparsky 1979). This puts the /s/ outside of the 'true' onset for /sp, st, sk/, possibly creating an advantage for the moraic stimuli presentation (C-CV), where one of those stops was the second consonant of the cluster.

## Results: Part I—Block 1

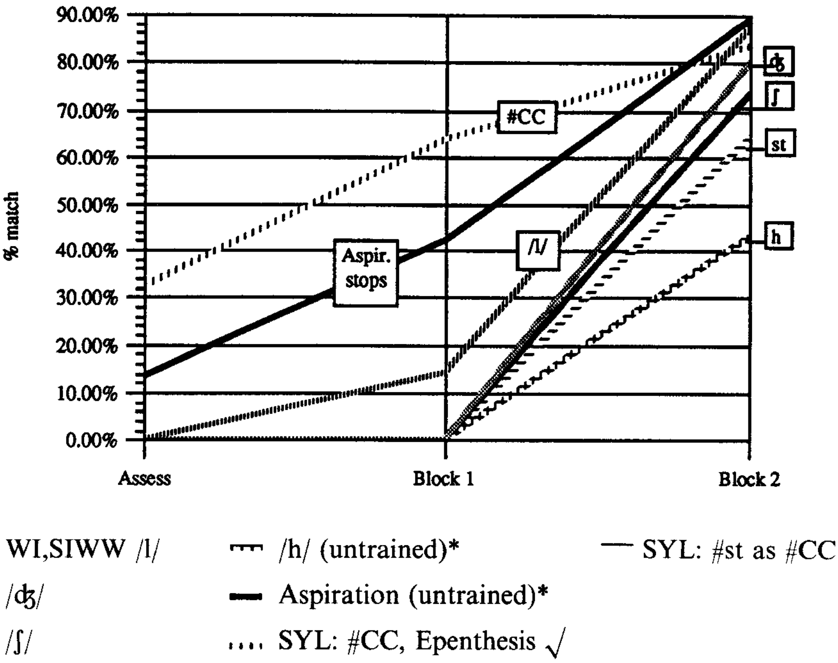
### *Prosodic versus segmental tier targets*

Table 6 and Figure 3 show gains in proportional matches for trained and untrained segmental and prosodic targets. (Further details of pre- and post-match levels and proportional gains are in Appendix 3.) For trained targets the overall proportional

Table 6. *Proportional gain in matches for all targets between assessment and the end of Block 1, and between Block 1 and the end of Block 2*

| Tier | Target | Percentage gain Assess > Block 1 | Percentage gain Block 1 > Block 2 |
|---|---|---|---|
| PROS[a] | WI CC[a] slots for all clusters—disyllabic word (no epenthesis) | 33·94 | −20·10[b] |
| PROS | WI CC slots for all clusters—monosyllables (no epenthesis) | 13·50 | −30·77 |
| PROS | WI CC slots for trained clusters only—short epenthesis x | −14·74 | 48·81 |
| PROS | WI CC slots for trained clusters only—short epenthesis √ | 35·26 | 5·95 |
| PROS | SIWW CC—untrained (short epenthesis x) | 17·50* | 16·35* |
| | SIWW CC—untrained (short epenthesis √) | 17·50* | 47·12 |
| SEG | WI /l/—trained | 15·00 | 55·59 |
| SEG | SIWW /l/—trained Block 2 only | 0* | 100·00 |
| SEG | WI /Cl/—trained Block 2 only (short epenthesis √) | 5·26 | 94·74 |
| SEG | /ʤ/—trained | 0* | 80·00 |
| SEG | /ʃ/—trained | 0 | 73·91 |
| SEG | SF /l/—untrained | 0* | 23·53 |
| SEG | /ʧ/—untrained | 0* | 55·00 |
| SEG | Aspiration of WI stops—untrained | 28·80[c] | 46·82 |
| SEG | /h/—untrained | 0* | 42·86 |
| SEG | WI 'complex/non-complex' distinction | −35·08 | 55·24 |
| SEG | WI /t/ > √ as non-complex | −29·00 | 36·84 |
| SEG | WI /s/ > √ as non-complex (all) | +20·00 | All again |
| SEG | WI /ʃ/ > √ as non-complex (all) | +50·00* | −16·67 |
| SEG | WI affricates > √ as complex | −18·04 | 52·96 |
| PROS | Overall gain: All CC slots—short epenthesis x | 21·79 | −20·81 |
| PROS | Overall gain: All CC slots—short epenthesis √ | 37·21 | 19·72 |
| SEG | Overall gain: trained segments | 5·88 | 61·56 |

[a]PROS = Prosodic tier; SEG = segmental tier; WI = Word-initial; SIWW = Syllable-initial-within-word; SF = syllable-final; CC = consonant cluster. Raw proportions for each probe (from which proportional gain differences were calculated) were based on a minimum of 10 tokens, except for those targets indicated by asterisk (*), which had fewer than 10 tokens per probe. For raw numbers, see Bernhardt (1990).
[b]More clusters appeared with short epenthesis in Block 2, resulting in 83% of WI clusters being realized with two consonants.
[c]There were no other Block 1 segmental inventory changes, i.e. for /r/, /θ/, /ð/, /h/, or /ʒ/.
[d]There were no other Block 2 segmental inventory changes, i.e. for /r/, /θ/, /ð/, or /ʒ/.
Note: epenthesis between cluster consonants counted as match (√) and non-match (x).




Note: At Block 2, /l/ data includes clusters (100%, short epenthesis ignored as an error). Clusters having very short epenthetic vowels were designated as matches. When epenthetic vowels were as long as other unstressed vowels (according to E's transcription), the child form was counted as a prosodic mismatch.
Epenthesis facilitated the appearance of two consonants for CC clusters, and also 3/6 WI CCC clusters in the Block 2 probe.

*No other segmental changes were noted over time, i.e., for observation targets /r/, /ð/, /θ/, or /ʒ/.

Figure 3. *Developmental progression in proportional matches across the intervention period.*

gain was greater for the prosodic tier condition, i.e., realization of two consonant cluster slots (21·79%, or 37·21% if short epenthesis was ignored as a mismatch†) than for the segmental tier condition (5·88%).

### *Segmental tier targets*

1. Lower level feature [−anterior]: no alveopalatals produced during the major probe.

† Epenthetic vowels appeared in increasingly greater numbers of WI clusters. The epenthetic vowels differed noticeably in length, some being barely audible, and others being equivalent to unstressed vowels. Throughout the results section, match calculations are presented both with and without short epenthesis counted as a mismatch. In the Block 2 major probe, long epenthetic vowels appeared most frequently in spontaneous single words, whereas clusters without epenthesis or with short epenthetic vowels appeared most frequently in connected speech utterances. Thus, epenthesis was possibly more a phonetic pronunciation variable, rather than a significant phonological error.

2. Higher level feature [+consonantal] (in conjunction with [+sonorant]): 3/20 (15%) SI /l/ tokens (all spontaneous, and two in connected speech) and one /bl/-cluster (spontaneous—*blah-blah-blah*). Three non-matching tokens (two spontaneous, one echoic) were specified for [+consonantal] but had a vocalic onset [ᵘl].
3. Observation targets:

*Predicted feature generalizations from segmental target training*
'*Complex*' specification: *S* marked the contrast between WI complex and non-complex segments more accurately for the fricative coronals (100% matches for this distinction), but had an overall regression in terms of the complex/non-complex distinction. Seven of 14 WI /t/ targets were realized as affricates, and 17 of 19 WI affricate targets were realized as fricatives.

*New feature specifications not predicted by segmental target training*
Laryngeal node: range of distribution for allophonic redundant feature [+spread glottis] expanded in the WI stop category (22/52 matches for aspiration, 42·31%).

*Reduction in default use not predicted by segmental target training*

(a) Root node: [+*continuant*] for the first element of [w]-clusters was reduced in range of application to /t/- and /d/-clusters only.
(b) Place node: *Labial* for Coronal Place was reduced in range of distribution, applying now to /t/- and /d/-clusters, /r/, and /θ/ only.

*Prosodic tier targets*

The proportional gain for skeletal slot realization of WI disconsonantal clusters was 13·5% for single-syllable words, and 22·26% across all word shapes (counting all items with epenthesis as mismatches, i.e. with a stringent criterion). For SIWW clusters there was no overall improvement of 17·5%. The actual target clusters—/Cw/ and /Cj/—showed a decrease in matches when short epenthesis was counted as a mismatch, but an increase similar to that for clusters in WI disyllabic words, i.e. a high gain.

1. Moraic sub-block
   /kw/: Because of consistent epenthesis use, no exact matches were noted for /kw/ in the major probe, although the /k/ and /w/ elements matched as segments within the clusters in all four instances.
   /kj/, /pj/: 100% matches
2. Onset-rime sub-block
   /tw/: No matches were noted for /tw/ in the major probe, and /t/ was correct only twice in five attempts. (For /t/, [f] surface twice and [d] once.)
   /fj/, /vj/, /mj/: There appeared to be some progression in realization of the /mj/ clusters, in that one production had a rounded front vowel for /ju/ (/mju/ >[my] in *musicwriting*), but there were no matches. (No major probe words were collected with the fricative clusters.)
3. General changes in cluster realization.

Overall there was a dramatic change in initial cluster production with (1) elimination of the [f] assimilation for all but /t[w]/ and /d[w]/, (2) realization of most /s/-clusters with both elements, and (3) an increase in the use of epenthesis between consonant cluster elements (epenthesis with either full vowels, i.e. CV.C, or very short reduced vowels, i.e. $C^v$.C). Counting items with short duration epenthesis as prosodic matches, 64% of the child forms matched the cluster targets in terms of skeletal slots (without these items, 50·67% were matches). (Of all of the WI disconsonantal clusters, the only one without two elements in the major probe was /st/.)

### *Intervention plan: Block 2*

*Segmental tier targets*

1. Lower level feature: Coronal node [−anterior] (*as in Block 1*)
   Training segments: /ʃ/ and /ʤ/ (all word positions)
   Untrained observation segments (multiple baselines with the same feature): /ʧ/ and /ʒ/
2. Higher level feature: [+consonantal] in conjunction with [+sonorant]
   Training segment: WI and SIWW /l/, WI /l/-clusters (*new contexts*)
   Untrained observation segment: /r/
3. Other untrained observation targets: Coronal stops and fricatives, /h/ and aspirated voiceless WI stops (i.e., as before)

*Rationale for segmental target selection*
*S* had not mastered the Block 1 segmental targets, and hence they were repeated. Because WI clusters were developing rapidly in terms of skeletal slot establishment, /Cl/-clusters were considered viable segmental goals at this point.

*Prosodic tier targets*

1. Moraic sub-block
   Targets: /kw/ (one half-session for generalization to conversation)
   /st/ in WI position
2. Onset-rime sub-block
   Targets: /tw/ (one half-session for generalization to conversation)
   /st/ in WI position
3. Observation targets
   Triconsonantal syllable-initial clusters, with respect to the main goal of realization of all cluster slots, /tr/- and /dr/-clusters

*Rationale for prosodic tier condition target selection*
The /Cw/-clusters were briefly retargeted in order to enhance their use in conversation.

Of all of the WI disconsonantal clusters, the only one without two elements in the major probe was /st/. In WF position, /st/ was established in terms of skeletal slots and in one case /ts/ was produced as a phonetic match ([ts] rather than [tθ]). Choosing a prosodic tier target which would require some phonetic (and therefore) segmental training was a departure from the general design. Because the only other option was triple consonant WI cluster training (which would also involve /s/), and because of the general need to address the WI /s/ and /t/ neutralization, *E* decided to proceed with /st/ as a prosodic target. The data were analysed separately in terms of WI skeletal slots (CC) and in terms of feature matches for the /s/ and /t/.

Utilizing the same target for both conditions provided an opportunity to evaluate the effects of introducing stimuli as onset-rime versus moraic constituents without the influence of phonemic factors (note concerns re /tw/). In order to minimize the intercondition interference, an attempt was made to match lexical item to condition so as to maximize independence and meaningfulness of stimuli, for example, *day/stay* for moraic, in which adding an initial [s] to an unaspirated stop provided two words for contrast, versus *and/stand* for onset-rime, in which the addition of [st] provided two words for contrast.

## Results: Part II—Block 2

### *Prosodic versus segmental tier targets*

Minor and major probe results are reported (see Tables 6 and 7, and Figure 3). Table 7 shows a greater gain for the prosodic tier targets on the minor probe, but a greater gain for the segmental ones on the major probe. Between the minor probe for segmental targets and the major probe at the end of the block, a month intervened. The minor probe and the major probe for the prosodic targets were, on

Table 7. *Proportional matches in the Block 2 minor and major probes*

| Tier | Target | Minor probe (% match) | Major probe (% match) |
|---|---|---|---|
| Pros[a] | MOR: /kw/: epenthesis √ | 100·00 | 75·00 (3/4) |
| Pros | MOR: /kw/: epenthesis x | 69·57 | 50·00 (3/4) |
| Pros | OR: /tw/: epenthesis √ | 76·19 | 100·00 (1/1) |
| Pros | OR: /tw/: epenthesis x | 47·62 | 100·00 (1/1) |
| Pros | /st/: TOTAL—CC skeletal slots | 64·71 | 44·44 (4/9) |
| Seg | WI /l/—trained | 22·22 | 70·59 |
| Seg | SIWW /l/—trained | 33·33[c] | 100·00 |
| Seg | /Cl/—trained (epenthesis √) | 15·38 | 100·00 |
| Seg | SF /l/—untrained | 0·00 | 23·53 |
| Seg | SI /l/ + /Cl/—trained | 20·00 | 90·00 |
| Seg | TOTAL: /l/ (epenthesis √) | 18·52 | 68·42 |
| Seg | /ʤ/—trained | 11·11 | 80·00 |
| Seg | /ʃ/—trained | 58·82 | 73·91 |
| Seg | /ʧ/—untrained | 36·36 | 55·00 |
| Seg | Total: Alveopal.[b] | 39·47 | 65·57 |
| Seg | Affricates—Complex √ | 80·00 | 72·00 |
| Seg | WI obstruent—√ as non-complex | 62·50 | 87·50 |
| Seg | /h/—untrained | 0·00 | 42·86 |
| Seg | Aspiration: WI stops—untrained[c] | 50·00 | 89·13 |

[a]Pros = prosodic tier; Seg = segmental tier; MOR = moraic; OR = onset-rime, WI = word-initial, CC = cluster. Proportions are based on at least 10 tokens per probe unless otherwise indicated.
[b]No WI alveopalatal matches; 6/19 SIWW matches (no/ʤ); 9/13 WF matches.
[c]No other segmental changes for untrained targets.
Note: epenthesis between cluster consonants counted as match (√) and non-match (x).

the other hand, 1 week apart. During the prosodic sub-block period, generalization to conversation occurred for the segmental targets.

Ignoring short epenthesis as a mismatch, best minor probe results were achieved for prosodic tier targets /kw/ and /tw/. The lowest number of matches were for segmental targets /ʤ/ and /l/. However, if all cases of epenthesis are counted as mismatches, segmental target /ʃ/ had a greater match proportion than prosodic targets /tw/, and an only slightly lower match proportion than prosodic target /st/ (CC).

The overall proportional gain between major probes was 61·56% for segmental targets, compared with, variably, an increase of 19·72% for CC skeletal slot targets—epenthesis ignored as a mismatch—or a regression of −20·81%—epenthesis counted as a mismatch. For the major probe, best results were achieved for segmental targets SIWW /l/, /Cl/ (short epenthesis ignored as a mismatch), /ʤ/, and /ʃ/. The apparent regression from the minor probe to the major probe for the target /kw/ reflects the low number of tokens (four) and particular difficulty with one item—*quarter*—produced once without a [w], and for /st/, difficulty with *star* and *starry* (six of the nine exemplars).

*Segmental tier targets*

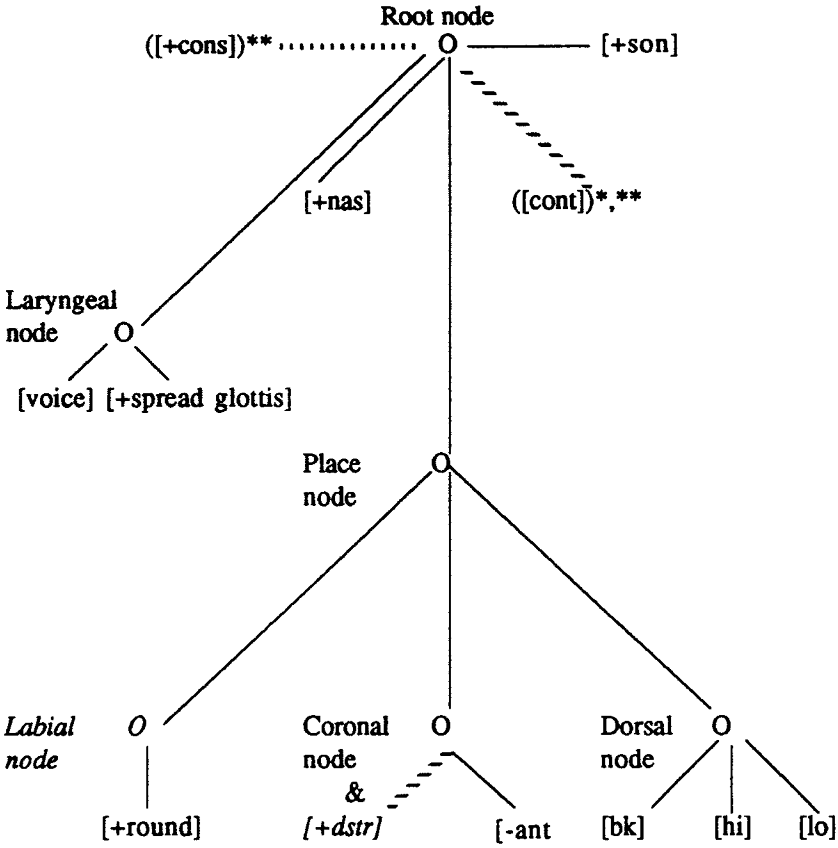
(1) Lower level feature [−anterior] (see Figure 4). At the onset of Block 2, *S* demonstrated an immediate imitative ability to produce the training targets phonetically, which he had not been able to do easily in Block 1. This phonetic facility occurred with no interim training, except for prosodic tier targets.

As noted, there was progress in the month between the minor and major probes. Of the 38 alveopalatals in the minor probe, 15 child forms matched the adult targets (39·47%), in comparison with none at the end of Block 1. However, the matches occurred for alveopalatals only in WF (9/15 matches, 60%) and SIWW positions (6/15, 40%), with no matching WI targets. In the major probe all alveopalatals except /ʒ/ were used in conversation. Forty of 61 (65·57%) child forms matched adult targets. As on the minor probe, there were unequal results across word positions and phonemes. In the minor probe the untrained /ʧ/ had more matches than its trained voiced cognate. This changed at the time of the major probe (on which there were more tokens of each), with better results showing for all trained alveopalatal targets. Best results were for trained targets WF /ʤ/ (100% matches) and /ʃ/ in SIWW and WI position (86% and 83·33% respectively). Over all word positions the rank order of matches was /ʤ/ (80%) > /ʃ/ (73·91%) > untrained /ʧ/ (55%) > untrained /ʒ/ (no matches on three attempts).

In terms of features, there were also unequal results across word positions on both probes. For example, at the time of the major probe, the 'default' feature [+*distributed*] was completely eliminated word initially and the feature [−anterior] always specified; in WF position, however, the feature [+*distributed*] was eliminated for the four /ʤ/ words and for six of the ten /ʃ/ words but not at all for the three /ʧ/ words (65% matches, a regression for the /ʧ/).

(2) Higher level feature: [+consonantal] in conjunction with [+sonorant]
Training segment: WI and SIWW /l/, WI /l/-clusters.

Between the minor and major probes there was also progress for /l/. During the major probe, generalization of /l/ was apparent across all word position, even though only SI singletons and clusters had been training targets. Overall, there were 27/45




Note: Parentheses indicate partially-established features in system development. Italics indicate inappropriately specified feature, e.g., labial place for voiceless interdental and /r/. Dotted lines indicate partial establishment.

*'Complex' branching structure inconsistently applied to affricates.

**[+cont] unspecified for the voice interdental; [+cons] unspecified for /r/ only and less frequent interdental tongue position for sibilants.

Figure 4. *Feature geometry at end of Block 2.*

(60%) matches for /l/ as a singleton. Results varied across word position, favouring trained word positions over untrained word positions. For SI positions, 82·14% of the words had matches (12/17, 70·59% for WI position, 11/11 for SIWW position). Among the clusters, ignoring short epenthesis, all had matches. Only /pl/ (42·86%) and /kl/ (33·33%) had matches, counting short epenthesis as a mismatch. In the untrained SF positions, two out of three SFWW items matched and two out of 14 (14·29%) WF items.

(3) Observation targets.

*Predicted feature generalizations from segmental target training*

'*Complex*' specification: specification or lack thereof for 'complex' structure improved for /t/ and /ʤ/ across the block, but some regression was noted for /ʧ/ from the minor to major probes.

*Feature specifications not predicted by segmental target training*

(a) Laryngeal node: redundant feature [+spread glottis] continued to show gains although untargeted, for more unvoiced WI stops (41/46 matches, 89·13%). Again, the focus on /t/ in the /st/ training may have influenced this outcome.
(b) Root node: [+continuant] specified for 6/14 WI /h/ words (42·86%).

*Areas of no change in feature specification for related and unrelated observation targets*

(a) Coronal node: [+*distributed*] interdental or dental place use continued for /s/ and /z/, in spite of progress with other coronals, and *Labial* for Coronal Place remained for /θ/.
(b) Root node: [+consonantal]/[+distributed] remained unspecified for /r/, in spite of progress with related training target /l/.

*Prosodic tier targets*

Major probe data were insufficient to compare moraic and onset-rime conditions. The minor probe data and the /st/ intervention session data are examined here.

(1) Moraic sub-block

(a) Minor probe data

Ignoring epenthesis, 23/23 (100%) matches were noted for /kw/. Acknowledging epenthesis as a mismatch, 69·57% of the items matched the targets.

(b) Session data for /st/ (skeletal slot results)

Overall, for moraic condition echoic responses, 82·64% of disconsonantal imitations matched *E*'s stimuli, and 90% of spontaneous responses matched, yielding a total of 87·78% skeletal slot matches in therapy sessions (see Table 8). In the introductory training sessions of this sub-block, *E* made word constituency salient with verbal and visual cues. For these introductory sessions, 94·44% echoic responses were correct, whereas 87·6% spontaneous responses were correct, yielding a total of 89·74%.

(2) Onset-rime sub-block

(a) Minor probe data

Ignoring epenthesis, 16/21 (76·19%) matches were noted for /tw/. Acknowledging epenthesis as a mismatch, 10/21 (47·62%) of the items matched the targets.

Table 8. *Block 2 session results for moraic and onset-rime conditions*

| | Imitated responses | | Spontaneous responses[a] | | |
|---|---|---|---|---|---|
| Condition | Introductory sessions[b] | Overall | Introductory sessions | Overall | Total |
| Moraic | 34/36 (94·44%) | 100/121 (82·64%) | 106/121 (87·6%) | 252/280 (90%) | 352/401 (87·78%) |
| Onset-rime | 54/59 (91·52%) | 71/78 (91·13%) | 34/37 (91·89%) | 67/86 (77·91%) | 138/164 (84·15%) |

[a]Includes all self-generated responses, including self-echoic responses and self-corrections.
[b]In the introductory training sessions, *E* made word constituency salient with verbal and visual cues.

(b) Session data for /st/ (skeletal slots)
Overall, for the onset-rime condition, 91·13% of echoic responses matched *E*'s stimuli and 77·91% of spontaneous responses matched, yielding a total of 84·15% matches (see Table 8). Examining the introductory sessions only, 91·52% of echoic responses matched, and 91·89% of spontaneous responses, yielding a total of 91·67%. There was a notable gap between the introductory sessions and total correct spontaneous productions of words assigned to this condition.

(3) Observation targets
Progress for untargeted clusters was observed.

(a) Triconsonantal syllable-initial clusters: 3/6 CCC matches (with epenthesis);
(b) /tr/- and /dr/-clusters: [fw] substitution eliminated; CC (1/7 no epenthesis; 4/7 with short epenthesis; 2/7 long epenthesis).

Because of the substitutions for /s/ ([θ]) and /r/ ([w]), cluster segments matched the adult target less than 50% of the time. As noted, epenthesis continued to be used in stop and approximant clusters.

Some overgeneralization from /st/ training was noted for /sw/, /spr/, /skr/, and /skw/, in which [t]/[θ]/[St] were optional substitutions for the stop or fricative, e.g. the /sw/ of *sweater* > [tʰᵘw] (2), [θtᵘw] (2), [θᵘw] (2), or the /skr/ of screwdriver > [tᵘw] (1) or [Stᵘw].†

*Comparison of moraic and onset-rime conditions across both blocks*
Scores were overall slightly higher for moraic condition targets across both blocks. However, the nonparametric Kolmogorov–Smirnov test statistic of (8)(7)(0·4625) = 25·9 (comparing cumulative frequency distributions of proportional matches for the two conditions) failed to reach the level of significance at the $p > 0{\cdot}1$ level (one-tailed).

## Discussion

Returning to the questions posed at the outset, the following interpretations are offered.

1. *Given that phonologists have shown that nonlinear frameworks account for the facts of phonology better than previous theories, will they help to predict logical and attainable intervention goals for phonologically disordered children?*

The nonlinear frameworks and concepts provided a coherent analytical basis for development of logical intervention targets. Changes in the system resulting in conversational intelligibility‡ demonstrated appropriateness of the selected targets. In the year prior to the study, and in the 4-month break following, no notable changes occurred in the child's phonological system, lending support to the perception of the project's success. I return to this general question in the conclusion.

† [S] = dentalized [s]
‡ Intelligibility is used here in a nontechnical sense.

2. *If the autonomy of prosodic and segmental levels of representation of nonlinear phonology is a psychological reality, (a) will intervention be effective if conducted separately for the two levels and (b) will there be a faster rate of change for the dominant prosodic tier?*

*Goal-setting and target selection*: It was possible to set up independent prosodic and segmental tier goals for both blocks—the *prosodic* tier goal of consistent SI disconsonantal cluster slot specification versus *segmental* tier targets of [+consonantal] in conjunction with [+sonorant] (/l/) and [−anterior] (the alveopalatals). The choice of training targets /tw/ and /st/ as prosodic cluster slot targets (SI CC) resulted in some overlap between conditions, because the coronals /t/ and /s/ were segmental observation targets. Although this detracted from the goal of overall autonomous intervention, it did demonstrate the effect of segmental tier constraints on realization of consonant slots. This may be evidence for a mediating skeletal tier, such that prosodic level prevocalic nodes may be linked to skeletal slots, but linkage between the skeletal slots and the segmental tier depends on the specification of the segments.

*Quantitative differences for training targets*
Independent development is evident from the notable difference in proportional gain between prosodic and segmental tier targets at the end of each block.

At the end of Block 1, there was a clear gain in percentage and types of syllable/word shape matches in comparison with segmental targets, the latter of which had not generalized to conversation. Practice with a few clusters containing well-established segments (the exception being /tw/, with its underspecified /t/) resulted in an increase in specification of cluster slots overall and a decrease in use of a default cluster—[fw].

Between the Block 2 segmental minor probe and the major overall probe at the end of Block 2, *S* achieved conversational mastery of the segmental targets trained in Blocks 1 and 2. This mastery developed during the prosodic tier sub-block, while segmental targets were not the focus of therapy or direct homework sessions, but did continue to be monitored at home in conversation. Although *S* continued to show progress for cluster slot realization (epenthesis notwithstanding), the rate of change decreased for prosodic tier targets in Block 2. The Block 2 differences between prosodic and segmental target outcomes possibly demonstrate another aspect of autonomous development. While conversational mastery of segmental targets was occurring, fewer learning 'resources' were available for new prosodic targets, even though they were the focus of training sessions and actual homework exercises. The prosodic target /st/ did not reach mastery level by the end of Block 2, although training influence could be seen in the appearance of /sCC/-clusters (with variants of /s/ and /t/) and overgeneralization of /s/ and /t/ to /sw/-clusters. Because /st/ also required segmental learning at the level of the coronal node, it was an expectedly difficult target (see above). Where two tiers interact, especially negatively as for /st/, we might expect a slower rate of change.

Thus, in response to the two parts of the question above:

(a) Targeting separate prosodic and segmental tier goals in an alternating format was a successful intervention strategy.
(b) A faster rate of change was noted for targets at the prosodic level, except

when realization of prosodic structure was impeded by segmental specification issues (i.e. neutralization among the coronals).

3. *Will there be a difference in proportion and rate of syllable/word shapes acquired as a result of interventions that contrast the onset and rime versus those that utilize the mora as a constituent?*

### *Quantitative analysis*

As noted, scores were overall slightly higher for moraic condition targets across both blocks. However, no significant differences between conditions were found overall using the Kolmogorov–Smirnov non-parametric statistic.

The similar results may reflect similarity of stimuli, either at the underlying level or at the surface level, the latter as a result of the type of constituent stimuli presented. Although the extreme versions of each constituent were used in presentation (see footnote on p. 301), stimuli may not have been completely contrastive as onset-rime versus moraic constituents.

The similar results may, alternatively, reflect response variables. Once a child is able to imitate a whole word correctly without imitating its separate constituents (e.g. [stɑp] versus [st]-PAUSE-[ɑp], or [s]-PAUSE-[tɑp]), a child may ignore any aspect of the condition that focuses on the stimuli in a particular way. The child's agenda at the point of whole word imitation is on using the word in as many (fun) contexts as possible.

The positive aspect of the observed lack of difference is that both types of constituent stimuli facilitated prosodic tier development. The use of both may have helped the child learn the syllable structure of English by 'breaking up' words in different ways.

### *Qualitative analysis*

Specific difficulty with the onset-rime target /tw/ was apparent in Block 1, reflecting difficulty with WI /t/ at the segmental level (the interdental default tongue position [+*distributed*]).

A factor not apparent in the training target data *per se* may indicate some general learning about clusters based on stimuli in the onset-rime condition. From the assessment to the end of Block 1 the use of epenthesis increased, enabling consistent realization of WI stops in clusters. Onset-rime sub-block training method may have promoted use of epenthesis, since the [w] or [j] of the [tw]-, [mj]- or [fj]-cluster was presented as an [$^{\text{ʊ}}$.w] or [$^{\text{i}}$.j] to make a pronounceable constituent separate from the rime, e.g., *twine* > [t$^{\text{ʊ}}$-wɑɪn].

4. *If one predicts that higher and, therefore, dominant features/nodes should have developmental precedence over subordinate features/nodes, is there any advantage to be gained from targeting specified features at higher versus lower levels in the feature hierarchy in phonemic inventory intervention?*

### *Block 1*

At the end of Block 1, three matching WI /l/ tokens (out of 22) appeared (with three other approximate non-matches [ᵘl]), whereas no alveopalatals matched. A faster rate of acquisition was thus evident in Block 1 for the higher Root node feature [+consonantal] conjoined with [+sonorant] over the lower level feature [−anterior]. Although the difference between three and none is quantitatively small, the difference between emergence and failure to emerge is qualitatively major in terms of acquisition.

### *Block 2*

At the end of Block 2, both sets of targets had generalized to conversation, demonstrating an apparent 'catch-up' effect for the [−anterior] feature, although trained word position targets for /l/ continued to have an overall higher match proportion than alveopalatals. One of the notable therapy observations at the beginning of Block 2 was *S*'s greater *stimulability* for alveopalatals at that point than in the whole of the previous block, even though intervention had focused solely on /l/ and the prosodic tier targets in the interim. The rapid increase in generalization of alveopalatals in Block 2 may indicate that phonological learning was being held back by articulatory (phonetic) factors for this set of targets.

Thus, although not definitive, a small amount of support is seen in terms of the relevance of height in the feature hierarchy for development and intervention. Targeting two features in the same time period may have resulted in mutual influence of higher and lower level features, particularly when one of the features is a *marked* feature (i.e. [−anterior]) of a default place node for the other (Coronal).

### *Feature generalizations*

Also in support of feature relevance are the generalizations noted above for related targets.

### *Changes for untrained related baseline targets*

Untrained targets which generalized to conversation from the trained ones were, as predicted, related to trained targets:

1. After training of [−anterior] segments /ʤ/ and /ʃ/, /ʧ/ appeared.
2. After training of [+consonantal]/[+sonorant] WI and SIWW /l/, SF /l/ appeared.
3. Facility with imitative production of [r] (unstimulable at the onset of intervention) may be attributed to the acquisition of /l/ and the alveopalatals, since /r/ requires the specification of [+consonantal]/[+sonorant] as well as a retracted ([−anterior]) tongue position. (However, no /r/ tokens appeared in probes, and /r/ was therefore targeted individually after a 4-month break.)
4. 'Complex/non-complex' distinctions became more clear-cut among coronals over the study, as a result of training from all conditions which had coronal obstruent targets. The least success in this regard was for /ʧ/, a related but untrained target.

### *Lack of changes for related baseline targets*

No changes were noted for [+anterior] coronals, altough one might have predicted that outcome as a result of training for the marked feature [−anterior]. The *default* feature remained [+*distributed*] rather than [+anterior], a reflection of the articulatory significance of the forward tongue position.

### *Changes for untrained unrelated baseline observation targets*

Unrelated untrained targets which improved unpredictably were:

1. Aspirated WI stops: this feature change possibly resulted from prosodic condition training, since aspirated isolated phones [$k^h$] and [$t^h$] were stimuli in training of the /k/- and /t/-clusters.
2. /h/: The latter was never presented in therapy, but may have improved as an extension of further delineation of the feature [+continuant] from /st/ training and alveopalatal training, or as a result of the progress for the postlexical feature [+spread glottis] for aspirated stops, [+spread glottis] being a possible redundant feature of /h/.

### *Lack of changes for untrained unrelated observation targets*

No changes were noted for /θ/ or /ð/ and none were expected to follow from the training done.

## Conclusion

Overall, the nonlinear frameworks provide a useful methodology for setting attainable goals for phonological intervention. In terms of analysis and goal-setting, the formalism of the frameworks presents a graphic description of a child's phonological system at a given time and, in comparison with the adult target, leads to logical goal-setting, based on a positive progression.

By targeting prosodic and segmental tiers independently, independent rapid development on one or the other level can lead to relatively immediate increased communication efficiency (see also Bernhardt, 1990, and Von Bremen, 1990, which demonstrated greater rate of change at the prosodic level first). Whether to begin with prosodic or segmental sub-blocks may depend on the need to gain a child's collusion in therapy. If segmental goals take longer to achieve, some children might participate more actively if prosodic tier targets are introduced first. However, short treatment periods may obviate the need to decide between initial major goal types.

The equivalency of results for moraic and onset-rime conditions suggests that stimuli presentation types may not matter in training. However, it may also be that contrasting different types of prosodic constituents (1) enhances a child's ability to perceive aspects of the speech stream and, from those perceptions, to derive more accurate representations, and (2) provides a child with practice in producing various kinds of phonological units, thus helping to break down phonotactic constraints which have an articulatory basis. Further examination of this issue is warranted.

The data from this subject (and others in Bernhardt, 1990, and Von Bremen,

1990) suggest that higher level features have a faster rate of acquisition, but again, further research is required to evaluate this question. Whether the higher level feature has precedence developmentally or not, it does appear that targeting two distinctive features at different hierarchical levels in the same *general* time period results in changes in more than one part of the segmental system, thus helping the child to learn the scope of the phonemic system for his language.

In sum, phonological theory continues to be assistive in the development of logical and viable approaches to phonological intervention.

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### Appendix 1: Consonant specifications for adult English[a]

| Segment | Root node | Laryngeal node | Place node |
|---|---|---|---|
| /m/ | [+consonantal], [+nasal] | | Labial |
| /n/ | [+cons], [+nasal] | | |
| [ŋ] | [+cons], [+nasal] | | Dorsal[b] |
| /p/[c] | [+cons] | | Labial |
| /b/ | [+cons] | [+voice] | Labial |
| /t/[c] | [+cons][d] | | |
| /d/ | [+cons] | [+voice] | |
| /k/[c] | [+cons] | | Dorsal |
| /g/ | [+cons] | [+voice] | Dorsal |
| /f/ | [+cons], [+continuant] | | Labial |
| /v/ | [+cons], [+cont] | [+voice] | Labial |
| /θ/ | [+cons], [+cont] | | Coronal: [+distributed] |
| /ð/ | [+cons], [+cont] | [+voice] | Cor: [+distributed] |
| /s/ | [+cons], [+cont] | | |
| /z/ | [+cons], [+cont] | [+voice] | |
| /ʃ/ | [+cons], [+cont] | | Cor: [−anterior] |
| /ʒ/ | [+cons], [+cont] | [+voice] | Cor: [−ant] |
| /ʧ/ | [+cons] (complex)[e] | | Cor: [−ant] |
| /ʤ/ | [+cons]; (comp)[e] | [+voice) | Cor: [−ant] |
| /w/ | [+sonorant][f] | | Lab |
| /h/ | [+cons][+cont] | LN | |

| | | |
|---|---|---|
| /j/ | [+son] | |
| /l/ | [+cons], [+son] | |
| /r/ | [+cons], [+son] | Cor: [+distrib] (or Lab+Cor Place) |

[a]The above encodings and the feature hierarchy diagrams for the subject presented in Figures 1 and 3 are derived from Sagey (1986). In addition, [+distributed] is used to distinguish interdentals from alveolars, and /r/ from /l/ (alternatively, Labial+Coronal Place for /r/). The feature [+nasal] is attached to the Root node, which then leaves the Supralaryngeal node basically a Place node (McCarthy, 1988). The mnemonic 'complex' is used to describe the branching structure of [continuant] for affricates (Lombardi, 1989). Only marked features are indicated as per a radical underspecification hypothesis.
[b]Although [ŋ] can be considered an allophone of /n/ in English, it is listed here to show feature markings at the phonetic level.
[c]Allophonic marking of [+spread glottis] is assumed for WI voiceless stops and the lack thereof is noted for the child data.
[d]The least specified consonant is /t/. This implies that marked features are [+consonantal], [+continuant], and [+nasal] at the Root node, [+voice] and [+spread glottis] at the Laryngeal node, and [−anterior] and [+distributed] at the Coronal node (itself the least marked node for consonants in English). The segment /t/ only needs to be specified for [+consonantal].
[e]Affricates are treated as having one Root node, although they appear to be units with two components. The branching structure of the affricates is indicated by the mnemonic 'complex', assumed to be [−continuant][+continuant] for English.
[f]In the above formulation, glides are uniquely [+sonorant] among the consonants. They are vowel-like in their specification but consonant-like in their syllable position. In this paper /j/ is assumed to have a Coronal Place node, following Halle and Clements (1983). The /w/ is then more complex because of its Labial Place node.

## Appendix 2: General outline for training sessions

Training sessions were audiotaped on the Marantz PMD220 using the AKG D310 microphone and Fuji FR-II tapes. All training words differed from probe words and the former contained no unestablished segments or word shapes except the target(s) for that sub-block condition. Sessions in all conditions followed this general outline:

1. Awareness training for the training target: mildly amplified stories, songs, poems, etc., which focused on the target (no vocal response required).
2. Auditory perceptual contrast training of the target and its error pattern with minimal or near-minimal pairs or trios (only at the beginning of a sub-block).
3. Imitation training with auditory, visual and physical cueing for the target in isolation, progressing through imitation and spontaneous training for the target in syllable/word shape, then sentence patterns, spontaneous sentences and, finally, conversation.
4. Practice in monitoring of others and self at the sentence level and above (contrast training part of this).
5. Tangible and/or social reinforcement for correct production at all levels, with special prizes being earned for use of set numbers of targets in conversation.
6. Parents in therapy sessions participating as models and respondents, with homework between sessions.

**Appendix 3: Proportional match data from assessment and major probes**

| Category | % Match | Match | Non-match | % Match | Match | Non-match | % Match | Match | Non-match | % Difference | % Difference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | BL. 2 | BL. 2 | BL. 2 | BL. 1 | BL. 1 | BL. 1 | Assessment | | | BL. 1-ASMT | BL. 2-BL. 1 |
| Pr: WI: CC-1 syllable | | | | 55·81 | 24 | 19 | 42·31 | 11 | 15 | 13·51 | |
| Pr: WI: CC-2 syllable | | | | 64·71 | 11 | 6 | 30·77 | 8 | 18 | 33·94 | |
| Pr: WI: CC-4 syllable | | | | 0·00 | 0 | 1 | 0·00 | 0 | 2 | 0·00 | |
| Pr: SIWW CC | | | | 37·50 | 3 | 5 | 14·29 | 1 | 6 | 23·21 | |
| Pr: WI CCC | | | | 0·00 | 0 | 6 | 0·00 | 0 | 4 | 0·00 | |
| Pr: total: Epen × | | | | 55·07 | 38 | 31 | 30·88 | 21 | 47 | 24·19 | |
| Pr: total: Epen √ | | | | 69·57 | 48 | 21 | 32·35 | 22 | 46 | 37·21 | |
| Seg: WI /l/ (ASMT: all | 70·59 | 12 | 5 | 15·00 | 3 | 17 | 0·00 | 0 | 35 | 15·00 | 55·59 |
| (WI, SIWW = 13) | | | | | | | | | | | 0·00 |
| Seg: SIWW /l/ | 100·00 | 11 | 0 | 0·00 | 0 | 1 | | | | 0·00 | 100·00 |
| Seg: /Cl/ | 100·00 | 12 | 0 | 5·26 | 1 | 18 | 0·00 | 0 | 13 | 5·26 | 94·74 |
| Sum: Trained /l/ | 82·14 | 23 | 5 | 14·29 | 3 | 18 | | | | 14·29 | 67·86 |
| /ʤ/ | 80·00 | 12 | 3 | 0·00 | 0 | 16 | | | | | 80·00 |
| /ʃ/ | 73·91 | 17 | 6 | 0·00 | 0 | 6 | | | | | 73·91 |
| /ʤ/ + /ʃ/ (trained) | 76·32 | 29 | 9 | 0·00 | 0 | 22 | | | | | 76·32 |
| /ʧ/ | 55·00 | 11 | 9 | 0·00 | 0 | 8 | | | | | 55·00 |
| ʒ | 0·00 | 0 | 3 | | | | | | | | 0·00 |
| Seg: Alveopal. | 65·57 | 40 | 21 | 0·00 | 0 | 30 | 0·00 | 0 | 30 | 0·00 | 65·57 |
| Sum: Trained | 67·44 | 29 | 14 | 5·88 | 3 | 48 | | | | | 61·56 |
| Seg: /h/ | 42·86 | 6 | 8 | 0·00 | 0 | 8 | 0·00 | 0 | 7 | 0·00 | 42·86 |
| Seg: Aspiration | 89·13 | 41 | 5 | 42·31 | 22 | 30 | 13·51 | 5 | 32 | 28·79 | 46·82 |
| Seg: Complex √ | 83·02 | 44 | 9 | 27·78 | 15 | 39 | 62·86 | 22 | 13 | −35·08 | 55·24 |
| Seg: Sum: Untrained | 74·38 | 90 | 31 | 93·88 | 46 | 3 | 20·78 | 16 | 61 | 73·10 | −19·50 |
| Seg: Tot.-observ. fea | 70·54 | 158 | 66 | 64·38 | 47 | 26 | 10·32 | 16 | 139 | 54·06 | 6·15 |

Pr = prosodic tier; Seg = segmental tier; Epen = epenthesis.

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