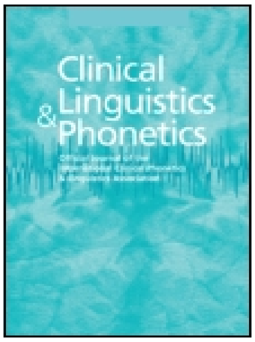

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Applying linguistic theory to speech–language pathology: the case for nonlinear phonology

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Abstract

Application of knowledge from many related fields benefits the practice of speech–language pathology. In the past 20 years, linguistic theory has provided a rich knowledge base for application. Phonological theories have provided frameworks for the description of the speech of unintelligible children in terms of coherent phonological systems, thus facilitating logical goal-setting for intervention. In this paper we suggest some of the possible implications of current nonlinear phonological frameworks for developmental phonology, and give an example of clinical application.

Keywords: Disordered phonology, nonlinear phonology, clinical applications.

In the past two decades speech–language pathology has benefited from advances in many related areas, but principally from applications of linguistic theory. The major impetus for changes in 'articulation therapy' came from the application of Stampe's natural phonology theory (1969). Several linguists and speech–language pathologists have described methods of phonological analysis which incorporate the natural phonology theory (e.g. Edwards and Bernhardt, 1973; Ingram, 1981; Hodson and Paden, 1983; Grunwell, 1985). Another stream of research (e.g. Elbert and Gierut, 1986) has applied rules of standard generative phonological theory whilst at the same time hypothesizing about the presence or absence of underlying representations. Application of phonological theories has appealed to those working with children demonstrating unintelligible speech, because generalizations can be made about a child's speech output which transcend 'substitution analysis' (including notations of omissions, substitutions and distortions). The child's speech output is instead described in terms of a coherent phonological system. Intervention is then devised to effect change in one or more major areas of the phonological system, i.e. over several segments or word positions.

Since Goldsmith's (1976) dissertation showing tone as an independently functioning autosegment, new and robust phonological frameworks have become available for application—under the general rubric 'nonlinear' phonology. Theories attain

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a robust status through their capacity to describe and explain facts about observed phenomena more parsimoniously than previous theories. By using robust linguistic frameworks for analysis and intervention planning, clinicians maximize opportunities for successful application. The purpose of this paper is to show how implications derived from some of the major tenets of nonlinear phonology have led to successful intervention (Bernhardt, 1990; Von Bremen, 1990). In the first part of this paper we outline some of the major aspects of nonlinear frameworks and suggest implications for developmental phonology which relate to each of those aspects. In the second part of the paper we discuss results of some intervention strategies based on these derived implications.

Nonlinear phonology

A major difference between previous 'linear', and subsequent nonlinear, theories is the latter's emphasis on representation rather than rules or processes. By accounting for more data in terms of multitiered representation, the range of possible rules or processes is greatly restricted and subject to a small set of general principles and specific parameters (Kaye, 1989).

Within a nonlinear framework, phonological representation now involves:

(1) the concept of autonomous hierarchical levels or 'tiers', rather than strictly sequential (linear) representations, and
(2) the incorporation of both prosodic and segmental information.

Phonological rules or processes result from, and are constrained by, principles of association between various tiers. Rules/processes are restricted to two basic operations—addition (linking) of 'phonological information' from one domain to another, and deletion (delinking).

General implications for developmental phonology

(1) *Representation over rules*: In terms of learnability, nonlinear theories suggest that a child comes to the language learning process with a universally determined and reasonably rich representational framework. A set of universally determined 'templates' are available for encoding information (Menn, 1978). Exposure to the input language(s) then both confirms the universally determined representation (e.g. that, as expected, the language contains stop consonants), and also results in 'setting' of parameters where (binary) options are available (e.g. that words are generally stress-final rather than stress-initial). It is suggested that rules/processes are minimal. When a child's system 'deviates' from the adult system, we see a combination of the universally determined 'templates' (as a result of delays in parameter setting) plus reflections of developmental constraints on perception and production.
(2) *Prosodic and segmental underlying representation*: The incorporation of both prosodic and segmental information in representation suggests that the child will come to the language-learning process primed with expected syllabic structure bases as well as with an expected segmental 'feature inventory'. Learning will involve setting parameters for syllable structure as well as features.

(3) *Tier autonomy*: The concept of tier autonomy implies possible independent learning for prosodic and segmental information.
(4) *Hierarchy*: The concept of hierarchy suggests a developmental progression such that dominant aspects of each system may be learned first.

Hierarchical representation

Further to the concept of hierarchical representation, separate tiers have been posited for larger prosodic units, such as the word, the foot and the syllable, as well as for smaller melodic units, such as the segment and its composite features. Many theorists also posit a 'mediating' tier (the 'skeletal' tier) between the prosodic level and the segmental level (Clements and Keyser, 1983; Levin, 1985). The following section describes the tiers.

Prosodic tier

Current frameworks agree that prosodic information should be incorporated in representation. In *Sound pattern of English* (SPE) phonology (Chomsky and Halle, 1968), however, stress was a feature assigned to the morpheme. This often failed to account for placement of stress in languages. SPE was also unable to account for well-formed sequences of segments within a language (Van der Hulst and Smith, 1985). Although syllable theories existed prior to SPE, the two types of phonological information—prosodic and segmental—were not linked in representation. To overcome this theoretical gap, phonologists developed the concept of a hierarchically structured representation with levels intervening between word and segment, which was termed metrical phonology.

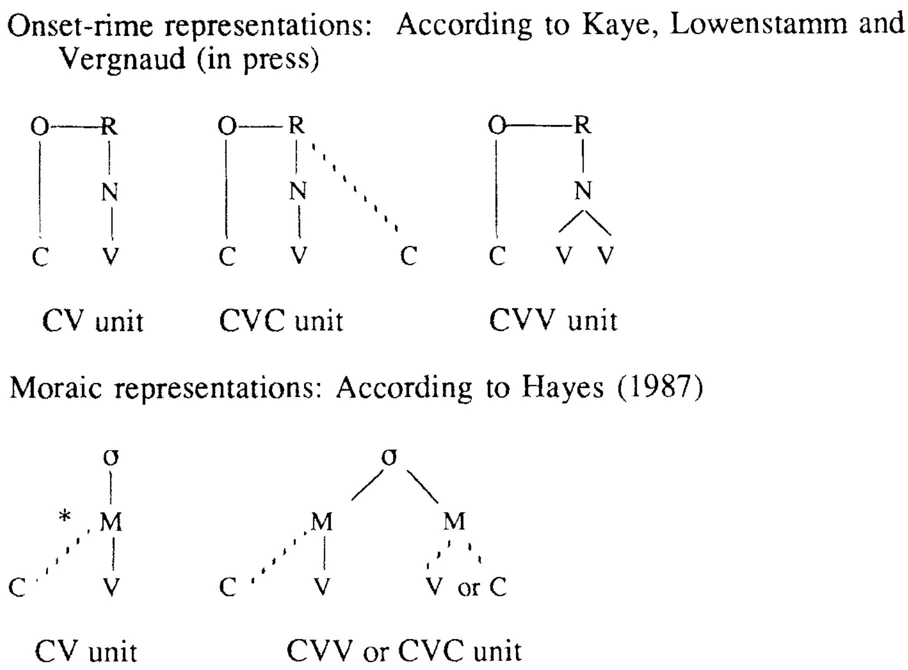
Although there is general agreement that segments group together in syllable-type constituents, two major alternative subtheories have been proposed to account for these groupings; namely, the onset-rime subtheory and the moraic subtheory (Fig. 1).

Onset-rime theory

Traditional onset-rime syllable theory was first introduced by Pike and Pike (1947), and is currently supported by Halle and Vergnaud (1980), Kaye, Lowenstamm and Vergnaud (1991)[1] and Steriade (1988) among others. In an hierarchical structure the onset (O) node dominates the prevocalic consonant(s), and the rime (R) dominates the nucleus (N)—a node intervening between the rime node and the most sonorant segment (usually a vowel). Postvocalic consonants are adjoined to the rime node.

In Fig. 1 we note a critical representational similarity between VV (diphthongs) and VC rimes. Both involve a *branching* structure within the rime which correlates

[1]Kaye, Lowenstamm and Vergnaud (1991) do not refer to a syllable constituent. They actually consider the O-R sequence to be the primary prosodic unit. For our purposes notational equivalency is assumed between syllable and O-R unit.



Key: O:	Onset	N:	Nucleus	VV = diphthong
R:	Rime	σ :	Syllable	
M:	Mora	V =	Vowel	

* In Hayes (1989), the prevocalic consonant is adjoined directly to the syllable node, but the research undertaken here utilized Hayes (1987), in which the prevocalic consonant is adjoined to the mora. The different level of adjunction does not crucially bear on the empirical consequences of this paper.

Figure 1. *Alternative representations of word/syllable constituents in onset-rime and moraic theories.*

with stress assignment in most languages, i.e. non-branching rimes do not attract stress.

Moraic theory

Hyman (1985) argues, however, that 'branching' may not be the critical factor for stress assignment. He points out that there are languages in which stress is assigned to those syllables with branching nuclei, but not to those with branching at the level of the rime node itself. Although one might suggest that the difference in level of branching may be a possible parameter for stress assignment (two levels necessary), Hyman and others (Hayes, 1989; McCarthy and Prince, 1986) posit that prosodic 'weight units' or 'morae' (M) are the critical constituents of syllables for stress assignment and other phonological phenomena. Weight units are realized through vowels (or other resonants). As Fig. 1 shows, morae may also be realized through postvocalic consonants in 'weight-sensitive' languages, where stress assignment is sensitive to certain postvocalic consonants as well as to the vowel constituents. Prevocalic and postvocalic consonants that do not contribute to the marking of syllable weight are simply adjoined to the mora or syllable (the level of adjunction being currently controversial). They do not form a particular constituent in and of themselves and, as such, have no particular independent phonological functions as prosodic constituents. Thus, in moraic theory, onsets by *representation* do not have a role to play in stress assignment, whereas in the alternative theory, onsets, although *branching*, cannot attract stress to the syllable.

Whichever formulation of the prosodic tiers ultimately accounts for the facts of languages, there is agreement that some version of hierarchical representation is necessary. (The formulation of Stonham (1990) incorporates both frameworks into one.)

Developmental implications of prosodic theories

(1) *Prosodic representation*: As stated above, a child probably comes to language learning with a universally determined basic syllable structure—CV, and possibly a 'minimal word' (bimoraic word—CVV, suggested in McCarthy and Prince, 1986. Exposure to the input language will result, for example, in learning what other syllable and word shapes need to be encoded (CVC, CVCV, CCCV, etc.), and how stress relates to the prosodic constituents (e.g. word-final or initial). This learning can occur independently of segmental (feature) inventory learning.
(2) *Onset-rime versus moraic structure*: Depending on the psychological reality of these formulations, development may progress in terms of branching structures (maximal and minimal, i.e. at the level of the onset or rime, or subnuclear), or in terms of weight unit specification.

As an example, according to O-R theory, a child who uses neither final consonants nor diphthongs continues to operate with the minimal structure required for the universally available O-R unit. Development for diphthongs and final consonants could occur independently, because of different levels of branching (see above).

Alternatively, the moraic theorist would claim that the child who uses neither final consonants nor diphthongs, in one syllable is operating with a *minimal* prosodic weight unit for a syllable—*viz.* one mora, or perhaps, a core syllable. For a weight-sensitive language such as English, once two morae are allowed per syllable, then both final consonants *and* diphthongs could appear in the child's prosodic inventory, since both the consonant and the second part of the vowel have phonological 'weight' as prosodic units.

The onset might be expected to show its own set of functions as a constituent (O-R theory) during development. Alternatively, prevocalic consonants may seem to be dependents of the mora or syllable, with no specific independent functions (moraic theory).

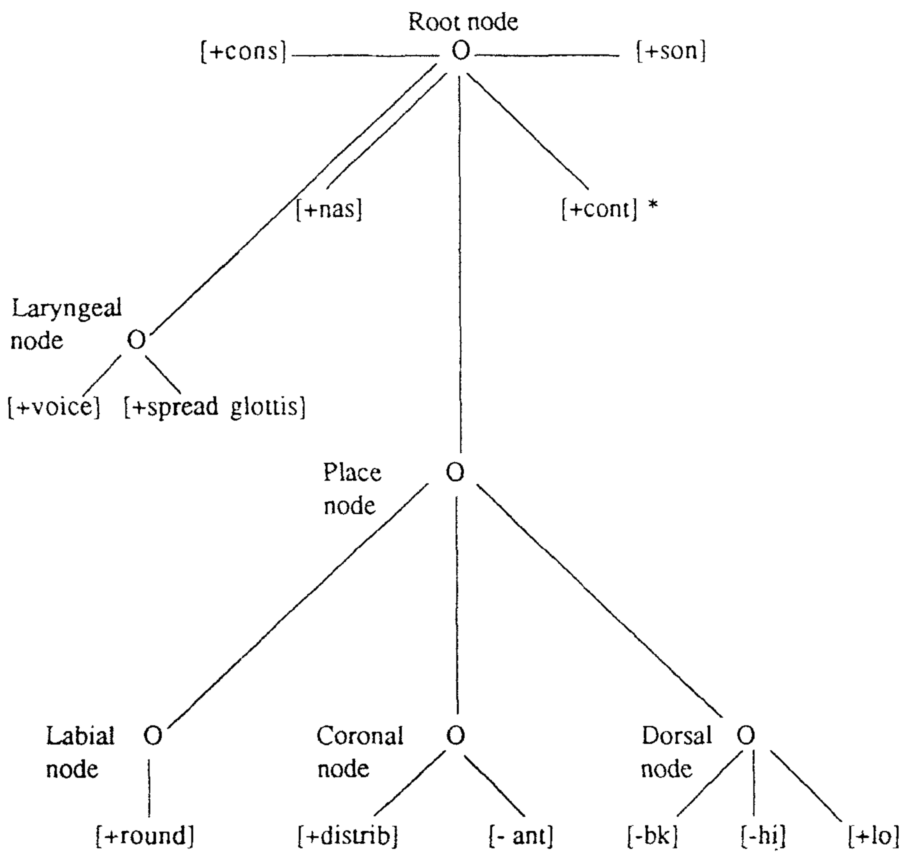
Segmental tier

Feature geometry

In SPE, Chomsky and Halle (1968) represented segments (phonemes) as linearly adjacent feature matrices, each feature being designated with a plus or minus value.

Clements (1985) proposed that segments were not composed of unordered bundles of features, but rather of geometrically organized features, each with some autonomy, but also with some dominance relationship with other features (see Fig. 2).

In terms of autosegmental properties, one feature of one segment can affect other similar segments in a domain such as a syllable or word (linking of only the feature [+nasal] from a nasal consonant to a vowel). In terms of dominance, whole groups of features can spread or be deleted (all oral place features so that all fricatives are realized as [h]). Thus certain features can group together in phonological rules/processes, because of their location in the hierarchy.



Note: Marked features are indicated on terminal nodes with plus or minus specification. Labial, Coronal, and Dorsal nodes are considered monovalent. The Root node designates the segment. It links into the prosodic tiers above. (See Appendix for more detail.)

*Affricates are designated as 'complex segments'. 'Complex' is a mnemonic describing the branching structure of affricates with respect to [continuant]. (The term is from Lombardi [1989] but does not imply her analysis.)

Figure 2. *Feature geometry for English.*

Another advantage of presenting a hierarchical arrangement of features is related to notions of markedness. Phonologists have observed that some features are more common than others. A hierarchical arrangement embodies this notion, in that deeply embedded features (e.g. [−anterior]) could be seen as more marked than 'higher-level' features ([+nasal]).

Proponents of nonlinear feature representations currently agree on a basic tree structure consisting of links between nodes, such as the one in Fig. 2 for English, modified from McCarthy (1988). Because languages have different segmental inventories, specified representations of the individual feature systems will differ for languages, but the general framework and set of marked and unmarked features is assumed to be universal. (Determining the set of universal and language-specific features and their relative markedness remains an ongoing enterprise in phonology.)

The nodes, as monovalent features or loci are as follows (see also Fig. 2 and the Appendix)

(1) *The root node*: This node links the segment to the prosodic tiers 'above'. Major class features [sonorant] and [consonantal] define the root node (and thus the segment) as a vowel/glide ([+sonorant]), consonant ([+consonantal]), or liquid ([+consonantal][+sonorant]).

The root node dominates the terminal features [continuant] and [nasal], traditionally classified as manner features, and defining classes of stops ([−continuant]), fricatives ([+continuant]), and nasals. (Since manner features never seem to function as a group in phonological rules, no separate manner node is posited. However, because they can be realized over different places of articulation, they are represented as dominant over place features in the geometry.) In this work the feature [continuant] was considered to have branching capabilities, from which affricates result ([−continuant][+continuant]).

The root node dominates both the laryngeal and place nodes.

(2) *The laryngeal node*: The laryngeal node defines the glottal characteristics of the segment. Terminal features include those for [voice] (and [spread glottis]). The latter feature may not be necessary except as a definition of postlexical aspiration of word-initial voiceless stops.

(3) *The place node*: The place node defines the oral cavity characteristics of the segment. It is a dependent of the root node above but dominates the individual place nodes—labial, coronal and dorsal. Clements (1989a,b) differentiates between consonant-place nodes and vowel-place nodes.

(4) *The labial place node*: The labial node refers to lip articulations (in English /w/,/p/,/b/,/m/,/f/,/v/, round vowels, and maybe /r/). It is linked to the higher-level place node and dominates a terminal feature [round].

(5) *The coronal place node*: The coronal place node refers to articulations of the tongue blade and tip (/j/,/t/,/d/,/s/,/z/,/ʃ/,/ʒ/,/ʧ/,/ʤ/,/r/,/l/,/n/,/θ/,/ð/). It is linked to the place node above and dominates terminal features [anterior] and [distributed]. Alveopalatal segments are considered [−anterior] and /θ/ and /ð/ (and perhaps /r/) [+distributed]. Coronal place is considered the universally unmarked or 'default' place (Paradis and Prunet, 1990). When the coronal place node does not dominate any terminal features, it is in this account assumed to be a default place at the level of the place node, i.e. at a higher level than labial or dorsal place nodes.

(6) *The dorsal place node*: The dorsal place node refers to articulations of the tongue dorsum (/k/,/g/,/ŋ/ and vowels). It is linked to the place node above and dominates terminal features [high], [low], and [back].

Underspecification

A further hypothesis about segmental representation concerns the concept of underspecification. Those who argue for underspecification claim that underlying representations of segments are minimal, containing information only about the idiosyncratic (distinctive) properties of the constituent. For example, a segment which is [+sonorant] may be considered underspecified for [voice]. The [+voice] feature is predictable, given the [+sonorant] feature.

With respect to which features must be encoded in representations, there is convergence of opinion on some issues, but disagreement on others. Proponents of 'radical underspecification' (Kiparsky, 1982; Pulleyblank, 1986; Archangeli, 1988) claim that the underlying representations include 'only unpredictable values for features' [whereas] 'predictable values are inserted by rule during the course of the derivation' (Archangeli, 1988, p. 192). Proponents of 'contrastive specification' (Clements, 1987; Steriade, 1987) claim that underlying representations include values for features 'only where that feature is being used to distinguish segments in the respective contexts; noncontrastive values are left blank' (Archangeli, 1988, p. 191). For work on disordered phonology we assume the position of radical underspecification. The Appendix lists consonants of English and the specified feature values assumed for each of them. In this formulation, /t/ is the underspecified consonant. The only specified value for /t/ is postulated to be [+consonantal] with all other 'features' of /t/ being predictable as unmarked features of language ([−continuant], [−nasal], [−voice], coronal place [+anterior], [−distributed]).

Developmental implications of the feature hierarchy and underspecification

(1) *Feature geometry (hierarchical representation)*: A possible developmental progression can be suggested in terms of position in the geometry. Using such a formulation, more deeply embedded features (details of place or glottis) should be learned later than major node features, particularly those at higher levels in the hierarchy.

(2) *Manner features*: As dominating features at the root node level, manner features could apply or fail to apply to all place features at once through the place node (all or nothing for fricatives), or be blocked from applying to all at once because of the autonomy of each place node (/m/ develops independently of /n/).

(3) *Underspecification*: In terms of development, input will both confirm default features and values as part of the phonology of a language and present evidence for their specified values. As input evidence accumulates and the child's phonological productive capacity matures, a child would be expected to add specified values gradually to the set of universally unspecified features. 'Default' segments can be expected early in acquisition, those determined by a minimum requirement of feature specification (rather than by a set of rules

or processes). The specifications in the Appendix suggest that English default consonants might be coronal stops, /j/, and /h/. Misperceptions (e.g. [f] for /θ/), articulatory/laryngeal immaturity (creating overvoiced segments or dentalized sibilants), or structural abnormalities (e.g. a cleft of the palate) may result in 'defaults' that do not match those of adult language.

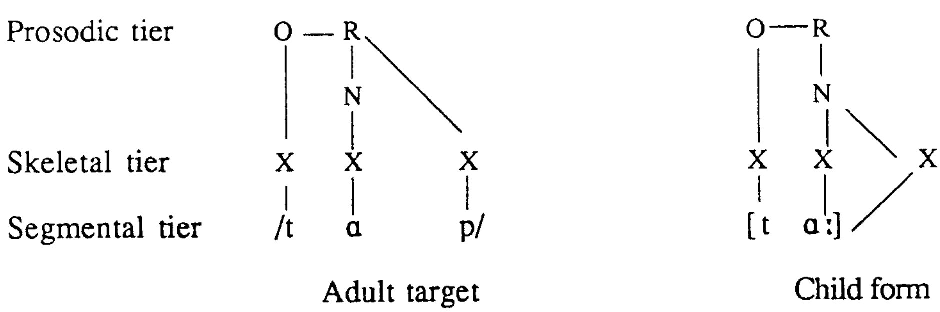
As a child learns what needs to be specified, under- or overgeneration of the newly learned specification may occur. Underspecified 'defaults' may be particularly susceptible as marked values are learned ([gɑg] for /dɑg/ example). In a developing phonological system, when representational and/or articulatory constraints block two places of consonant production within one syllable (or O-R unit), those segments which have specification can dominate the underspecified coronal place node, with specified features spreading to that empty node. Eventually, pressure to conform to the adult language and increasing representational/articulatory abilities result in accommodation of both specified and unspecified consonants within a syllable.

Skeletal tier

As noted above, some phonologists posit a mediating tier between the syllabic and segmental tiers—what has been called the skeletal tier (see Fig. 3). Kaye (1989) describes this as a level of timing units. Some phonologists refer to this as a CV tier (Clements and Keyser, 1983; Christdas, 1988), suggesting that some information relative to segmental type is represented at this level. Others refer to this as the X-tier, which only designates 'slots' for segments, with consonant and vowel information considered unnecessary (e.g. Levin, 1985). Moraic theorists such as Hayes 1987, 1989) link morae directly to segments without an intervening level. The morae themselves actually have a mediating role, with the notable exception being non-moraic units such as onset and postmoraic coda consonants.

Developmental implications of a skeletal tier

Evidence of a skeletal tier may be suggested in cases of partial establishment of a word/syllable shape. For example, if a CVC word is realized as CVV (as shown with



Key: O: Onset N: Nucleus
R: Rime X: Skeletal slot

Figure 3. *Association of prosodic, skeletal and segmental tiers in adult and child forms.*

[tɑː] for /tɑp/ in Fig. 3), a second rime constituent is assumed to underlie, but not be linked to, any consonantal segments. In the usual case, if a syllable constituent is not linked, principles of association then require deletion of it (which would create in this case an unbranching rime, i.e. with no vowel lengthening). If, however, a skeletal slot position is part of the underlying representation for this word, the syllable constituent is then linked to the skeletal slot, and therefore not deleted. For phonetic realization of the skeletal slot, spreading from elsewhere is required in the absence of an underlying consonant representation, i.e. from the vowel to the empty slot. Thus, the skeletal slot position acts as a placeholder in those cases where syllable-segment mapping is not one-to-one. However, whether the intermediate tier is needed for this eventuality depends on the principles of linkage elsewhere in the system, i.e. whether higher-level deletion necessarily occurs when linkage between prosodic and segmental tiers is absent.

Tier association

As stated previously, tiers are autonomous. However, they are links between them (linking associations appear in formalism as lines; see Figs. 3 and 4). There are basic principles for association of tiers which constrain and explain phonological rules/processes of linking (spreading) and delinking (deletion). Major principles state that:

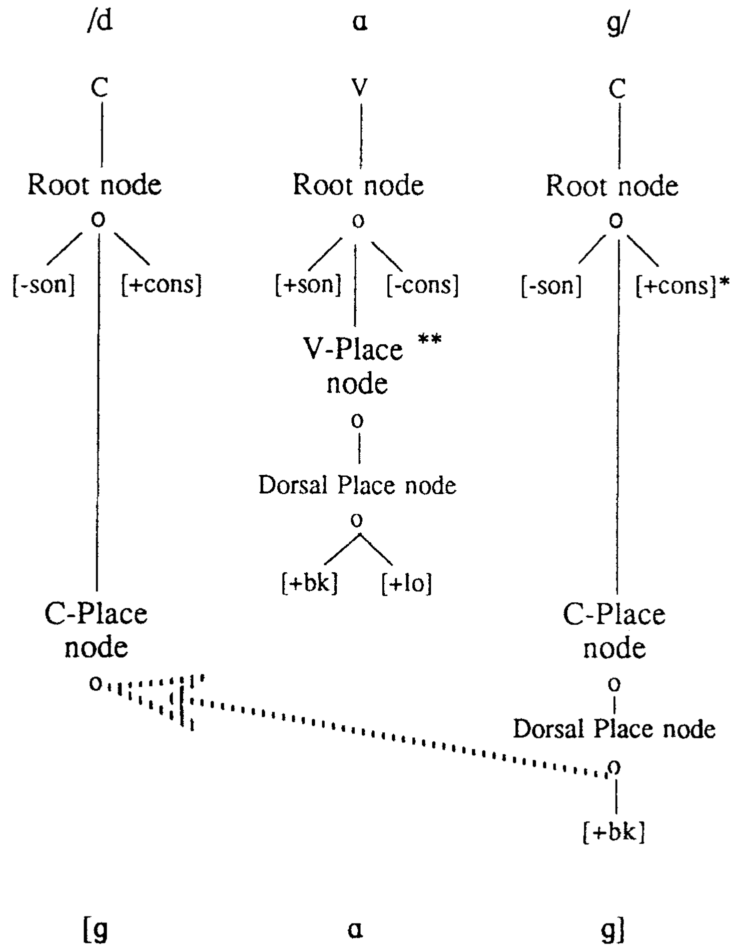
(1) one or more constituents may be linked to a constituent on another tier;
(2) association lines linking constituents must not cross, suggesting that operations may apply only to constituents adjacent at some level; and
(3) direction of association conforms to specific parameters (left-to-right or right-to-left).

Fig. 4 illustrates a nonlinear description of regressive consonant assimilation.

Hierarchical representations reveal adjacencies not apparent in surface representations. When /dɑg/ (*dog*) is realized as [gɑg], but /dɑl/ (*doll*) is realized as [dɑl], assimilation results from consonant–consonant interaction, rather than consonant-vowel interaction. The consonants, although separated by a vowel in the surface form, have to be adjacent at some deeper level of representation in order for assimilation, i.e. spreading of features, to take place. If they were adjacent at the level of consonant-place (C-place) node (Clements, 1989a,b), the dorsal place node of /g/ could spread to the C-place node for /d/ (an 'empty node' for reasons of 'underspecification'). If, on the other hand, vowels were tier-adjacent to consonants at all levels of representation, specified dorsal place node features of the vowels would block dorsal place consonant feature spreading (according to standard nonlinear interpretations of spreading, such as Archangeli, 1988).

Developmental implications of tier association principles

As mentioned in the first section, a major implication of the concept of tier association principles is the limitation of types of phonological phenomena. Thus, a child's system can be described in terms of a representational framework which constrains the number and types of processes/rules which can occur. There is much less 'phonological activity'. Rather, a passive 'filter-type' encoding system either allows or disallows encoding of certain word or syllable shapes and feature complexes,



* Only salient features for each example are shown.

** According to spreading conventions, if two adjacent segments have identical specification, spreading of those features from one of them to a third is blocked by the second. (Association lines must not cross.) Following Clements (1989a, b) consonant and vowel Place nodes are independent and therefore spreading of Dorsal Consonant-Place node to an adjacent C-Place node is possible because the Vowel-Place node is on an independent (and therefore nonadjacent) tier. Other representations are possible, but this is used to illustrate consonant adjacency, spreading, and linking.

Figure 4. *Regressive consonant assimilation in the absence of CV interaction.*

depending on their convergence with universally determined defaults and specifications 'learned' to date. Thus progressive learning takes place.

For example, according to rule or process analyses mentioned in the introduction, when a child produces input fricatives as stops, 'stopping' or deletion of [+consonant] is said to have occurred. Although rules of this type are accurate *descriptions* of the input–output relationship, however, their application implies a *negative* developmental process, that is, a process which must necessarily inhibit rules and processes (e.g. un-delete, un-front, un-stop, de-depalatalize).

Alternatively, by positing a representational 'filter' framework, development can be described as a positive progression. For example, in early phases of development, a feature such as [continuant] will surface with its *predetermined and redundant* negative value, until sufficient evidence for specification of a marked value of [+continuant] motivates change in the system. The marked value is not deleted from representation, but rather remains unspecified. This allows for development in which a child may perceive the feature, but be unable to produce it. Thus, a child can accept what he hears but does not need to match his output to the input unless he is misunderstood enough times to motivate change. By this account, learning proceeds in an additive fashion, when specification of the marked value occurs. In cases where a child's default feature or word shape is not that of his/her ambient language (e.g. when a child uses [+distributed] dental sibilants), perceptual or articulatory constraints may have influenced the predetermined values, or some salience of the feature/word shape either acoustically, or by overlearning, may have influenced the predetermined values.[2] (In this case some restructuring is necessary.)

Application of nonlinear phonology to intervention

We have now discussed some of the developmental implications of nonlinear phonology. For illustrative purposes we provide an example of the utility of nonlinear phonological analysis for intervention planning, as applied in Bernhardt (1990).[3] The Bernhardt (1990) intervention study took place three times per week over three consecutive 6-week blocks, using six phonologically disordered children as subjects. Both a multiple baseline and an alternating treatment design were employed. The multiple baseline design allowed comparison of treated and untreated parts of each child's linguistic system. The alternating treatment design provided a means to contrast condition types.

In this section we focus briefly on two aspects of the theoretical framework discussed in the first section: (1) the autonomy of the prosodic and segmental tiers, and (2) underspecification. We discuss the partial results from one subject, *S3*[4] in Bernhardt (1990), and the first block for the major condition types; i.e. intervention aimed at prosodic tier development versus intervention aimed at segmental development. It was hypothesized that autonomy of the tiers should allow for separate streams of development and hence independent goal-targeting. It was also expected that there might be a different, possibly faster, rate of change for prosodic intervention than for segmental intervention, since the theory proposes that the prosodic tier dominates the segmental tier.

Each of the prosodic and segmental training sub-blocks (i.e. 3 weeks each)

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[2]For purposes of this discussion we do not define 'salience' or 'overlearn'.

[3]For detailed elaboration of nonlinear approaches to intervention see Bernhardt (1990); Bernhardt (1991a, b) and Von Bremen (1990).

[4]*S3*, the second of two boys in his family, was aged 3;4–3;8 during the period reported here. Associated with his phonological disorder was a general delay in language production. Comprehension appeared to be within normal limits, as did general cognitive and motor skills.

encompassed nine sessions. The design for blocks 1 and 2 for *S3* is schematized in Fig. 5.

Analysis procedures

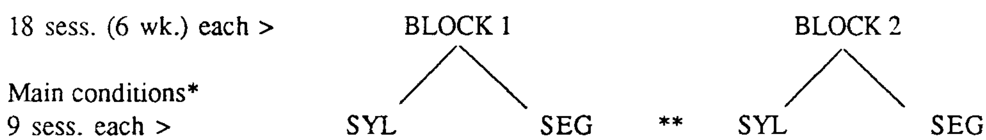
A standard word list (164 words) plus conversational samples provided audiorecorded data for an initial assessment for each subject, and the major probes at the end of each 6-week block. Narrow phonetic transcriptions were used to enter information into the database: (1) one chart for numerical accounting of segmental congruency/non-congruency with adult models, as well as type of non-congruency, i.e. omissions, substitutions, and feature differences; and (2) one chart for numerical accounting of the CV constituency of the words in comparison with adult models.[5]

The former set of charts were used for: (1) drawing feature trees for each subject, and (2) delineation of syllable position realization by segments (i.e. C_2 of C_1VC_2 limited to nasals). The latter set provided a database for description of the systems in terms of onset-rime and moraic frameworks. Intervention goals for each subblock were then derived.

In this paper we limit our descriptions of *S3*'s programme to an *overview* of the prosodic and segmental systems at initial assessment, and goal-setting and results for the first block.

Prosodic tier representation

The overview of prosodic level data is presented: in CV terminology and in terms of syllable position realization for segments. Possible prosodic tier intervention targets included two types: (1) unestablished or marginally established syllable/word shapes, e.g. CVC, CCVC, CVCVC, and (2) extension of segment or sound class word position realization. In the latter case it was assumed that dominance of the prosodic tier over the segmental tier implies that the 'developmental strength' of some syllable/word position determines licensing of segments, rather than the reverse (the 'template' view as discussed above).



*SYL = syllabic condition; SEG = segmental condition; 1 session = minor probe
**One week holiday

Figure 5. *Schematization of research design for* S3.

[5]Both of these charts had Grunwell's (1985) phoneme realization and CV confusion matrices as a basis for construction, but were elaborated versions of them. Her terminology for syllable positions is used in this text (SIWI = syllable-initial-word-initial; SIWW = syllable-initial-within-word; SFWW = syllable-final-word-final; SFWF = syllable-final-word-final).

Overview in CV terminology

Of the 431 reported target words, the total number of matches for syllable number and skeletal slot realizations was 153 (35·5%). The CV (46/48 matches) and CVV (23/28) units appeared to be established. However, all other permutations and combinations of syllable/word shapes were either developing or absent (see below). Overall, the system appeared to be characterized by word templates which were both syllabic and segmental in nature. Certain segments (i.e. nasals and [s]) closed syllables but, otherwise, word production was limited to open syllables, primarily one per word. The very frequent word-final [s] appeared as C_2 for both CVC targets and multisyllabic targets, the [s] often taking the place of entire syllables. The use of syllable-final nasals and [s] appeared to facilitate production of two tokens of a more complex word form:

monkey > [mâŋ.ɾɪs]
sewing machine > [mʌ̂n.dɪs]

Each syllable of this 'advanced' production conformed to an established monosyllabic word shape in the system—the first a CVC with a C_2 nasal, and the second a CV[s] syllable. Thus, when asked to repeat a disyllabic word, he utilized available syllable 'templates' to construct the more complex form.

Established word structures

Word structure matches were found for open monosyllables and reduplicated disyllables in the following order (percentages indicating proportion of matches):

(1) CV: 46/48 (95·83%)
(2) C_iVC_iV: 7/8 (87·5%) (but only *mommy*, *daddy*, i.e. two familiar partially reduplicated forms)
(3) CVV (VV = diphthong): 23/28 (82·14%)

Developing word structures

The following structures were developing at the time of assessment.

A. Monosyllabic targets

(1) CVC (overall): 99/136 (72·79%). CVC mismatches were due primarily to missing final consonants (37/136 [27·21%]) but also to missing word-initial (SIWI) consonants (17/136[12·5%]). (See segmental data below for details.)
 (a) CVC (excluding final /l/ or /r/ targets): 92/113 (81·42%)
 (b) CVC (excluding final /l/ and /r/ targets and [s] used for any final consonant except /s/): 66/113 (58·41%).
(2) VC: 7/11 (63·64%).

B. Disyllabic targets

Overall, 55/115 (47·83%) child attempts matched disyllabic adult targets for number of syllables. Also, 7/12 multisyllabic words (three or more syllables) were realized with two syllables. Presence of consonants in disyllabic targets was as follows:

(1) SIWI consonants: missing in 24/127 (18·9%) cases.
(2) SIWW consonants: missing in 13/55 (23·64%) cases (where two syllables were present in the child form).
(3) SFWF consonants: missing in 10/18 (55·56%) cases (where two syllables were present in the child form and [s] appeared as a SFWF substitution). The SFWF [s]-substitution appeared in 8/23 (34·78%) disyllabic child forms and in 31/39 (79·49%) monosyllabic child forms (i.e. reduced multisyllabic targets). In other words, [s] was used to close final syllables regardless of which other elements were missing.
(4) SFWW consonants: Two [n] realizations (see *monkey* and *machine* above), otherwise missing.

C. Diphthong development

As stated above, diphthongs were established in CVV type monosyllables. They were partially established in closed monosyllables (45·45%) and marginal elsewhere.

Undeveloped structures

The following were absent at initial assessment:
(1) Words of more than two syllables
(2) Consonant clusters post- or prevocalically

Segmental development

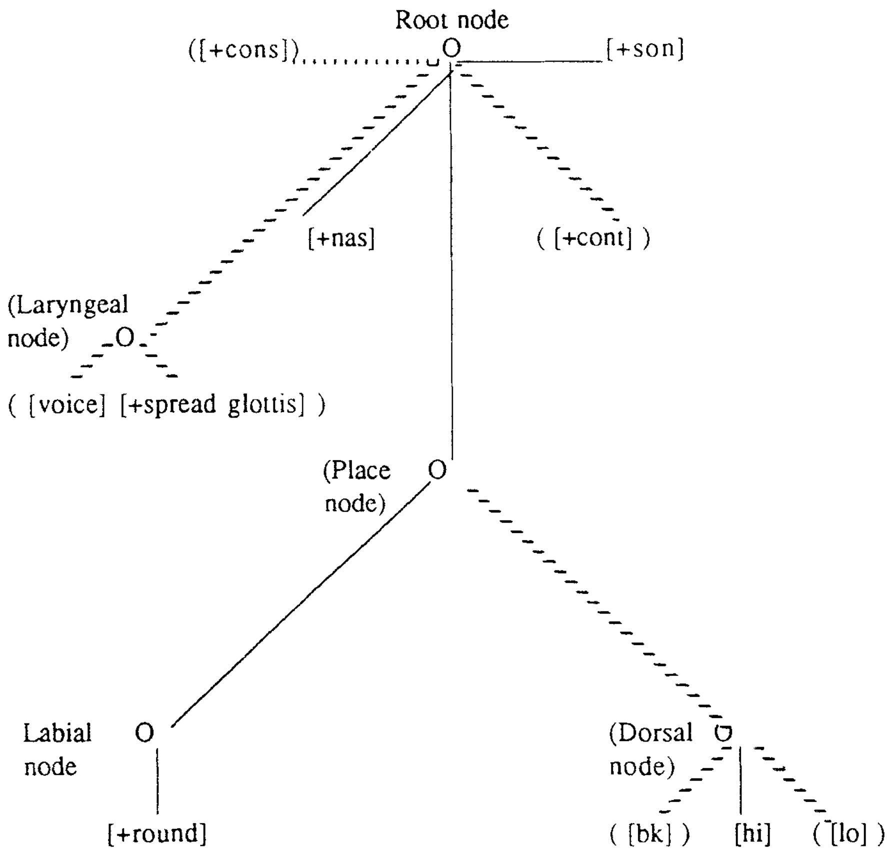
Figure 6 shows the feature hierarchy for *S3* at time of assessment. Table 1 shows manner class matches summed across word positions and category members with the following order of sound class establishment: glides > nasals > stops > fricatives (no affricates or alveopalatals) > liquids (no/r/).

Marked root node features [+continuant] and [+consonantal] in conjunction with [+sonorant] (i.e. for liquids) were least well established over all. The order of place node establishment (most to least) was labial > coronal > dorsal. Within each manner class there were salient members by place or voice, which, in the case of /s/ (overused as a word-final placeholder) and /f/ (one of the well-established labial place consonants), resulted in higher percentage matches than for fricatives over all.

Syllable position realization for segments

In terms of mapping between the prosodic and segmental tiers the following general pattern was observed. The order of match data across word positions was SIWI position (48·31%) > SFWF (36·23%) > SIWW (25%) > SFWW (8·33%). (SIWI and SFWF data include cluster data with the cluster counted as one element). Very frequent words with nasal and labial consonants, however, skew these percentages. Adjusted data (without /m/, /n/, and /w/) are as follows: SIWI (28·91%) > SIWW (25%) > SFWF (7·51%).

(1) The most well-established segment across word positions was /m/.



Note: Parentheses and dotted lines indicate marginal constituents in system development.

Figure 6. S3:*Feature geometry at initial assessment.*

(2) SIWI position: Established segments (80% matches or better) were /m/, /w/, /b/,/f/,/n/, and /v/. Partially established segments were /j/ (3/4) > /g/ (10/13) > /d/ (7/11) > /t/ (11/27) > /k/ (6/17) > /p/ (6/19) > /l/ (2/13) > /h/ (3/32).
(3) SFWF position: SFWF [s] was overused and had a 'default status.' In terms of underspecification, a 'default' segment is one which appears in high frequency as a substitution. When marked specifications are missing in underlying representation at the segmental level, but the syllable position is sufficiently strong to have segmental realization, the redundancy rules of the system provide ('default to') a set of unmarked features in order for pronunciation to occur. Other than the default [s], SFWF /m/ and /n/ were established. Marginal developments word finally were noted for /p/ (*up*—two tokens) and /t/ (1/4).
(4) SIWW position: The following segments appeared some of the time in SIWW position: /m/ (7/9) > /p/ (9/16) > /w/ (1/2), /b/ (3/6) > /f/,/s/ (1/3), > /t/ (2/15), /d/ (2/9).
(5) SFWW position: Only [n] appeared as noted for the two items above.

Table 1. *Sound class member establishment for singleton consonants over word positions at initial assessment for* S3 *(Bernhardt, 1990)*[a].

Manner class: relevant root node feature(s)	Total matches/manner category	Segment: place node feature(s)	Match ratio with adult targets summed across word positions	
Glide: [+sonorant]	53/62 (85·5%)	**/w/: labial place**[b]	**50/54**	**(92·6%)**
		/j/: coronal place	3/8	(37·5%)
Nasal: [+nasal]	165/221 (74·7%)	**/m/: labial place**	**86/91**	**(94·5%)**
		/n/: coronal place	78/106	(73·5%)
		/ŋ/: dorsal place	1/24	(4·2%)
Stop: [u continuant][c]	78/226 (34·5%)	**/b/: labial place**	**22/42**	**(52·4%)**
		/p/: labial place	17/39	(43·6%)
		/g/: dorsal place	10/24	(41·7%)
		/d/: coronal place	9/30	(30%)
		/t/: coronal place	14/52	(26·9%)
		/k/: dorsal place	6/32	(18·8%)
Fricative: [+continuant][d]	31/173 (17·9%)	**/f/: labial place**	**18/28**	**(64·3%)**
		/s/: coronal place	**9/39**	**(23·1%)**[e]
		/v/: labial place	1/11	(9·1%)
		/h/: laryngeal node	3/33	(9·1%)
Liquid: [+consonantal/ +sonorant]	2/60 (3·3%)	**/l/: coronal place**	**2/31**	**(6·5%)**
		/r/:coronal/labial place	0/29	(0%)

[a]No clusters in data.
[b]Bold face = best established member of manner category.
[c]u = unspecified in representation; [u continuant] = [−continuant].
[d]No other fricatives or affricates were produced.
[e][s] also appeared as a placeholding substitution in CV[s] productions of CVC or multisyllabic words.

Intervention Plan: block 1

In blocks 1 and 2, conditions for *S3* followed the pattern: syllabic/segmental. For each of the sub-blocks two major goals were selected (because of other subconditions). We focus here on the overall conditions only.

Syllabic intervention plan

In general, the goals were:

(1) to decrease the use of default SFWF [s] adjunction, thereby expanding the range of consonants realized in final position (CVC), and, if possible, the number of words produced with more than one syllable;
(2) to strengthen the disyllabic word shape.

The C_1VC_2V word shape was chosen as disyllabic target, because $C_iVC_iV(V)$ was established. Expansion of the range of permissible consonants in C_2 position (C_1VC_2V word shape) was the next logical step. Although targets were divided into onset-rime and moraic targets, we combine them here, since we are only looking at overall goals. Specific goals then were:

(1) CVC where C_2 = /p/
(2) C_1 VC_2V C_2 = /n/, /t, d/[6]

Rationale and methodology

The segmental data dictated choice of segments to insert into new syllable positions. To maintain as much independence as possible between segmental and prosodic conditions, only segments well established in some word position became targets.

Because this particular child was shy and sensitive about his speech delay, it was psychosocially necessary to find immediately attainable goals. Since the above segments had at least WI matching exemplars in the assessment sample, the potential for expansion of range of distribution across words was good. Informal probing prior to initiation of intervention indicated that the degree of use of the chosen targets was less than it had appeared during the assessment, making their choice justifiable. By targeting segments from two different manner classes (stops and nasals), two different place nodes (labial and coronal), and in two different word positions, Bernhardt (1990) hoped to enhance generalization across the system and to inhibit the default SFWF [s].

Segmental intervention plan

Marginally established segments (less than 10% matches), or those which had not yet been established, were possible training targets. Segments related and unrelated to the training targets, in terms of features, remained as observation targets. In order to select segments as training targets and observation targets, Bernhardt consulted feature specifications for English, relating features to the segments for which those features are distinctive (see Appendix). Since the goal was to establish features, more than one segment often became a training target during a feature sub-block. The syllabic data dictated choice of word position for target training. Only well-established word positions served as slots for insertion of new segments: this procedure was followed in order to maintain as much independence as possible between the segmental and prosodic conditions.

Because all segments except affricates and /r/ were used at least once in *S3*'s sample, either seemed the most likely segmental condition choices. Affricates were not chosen because: (1) establishing them would have entailed two types of specification, 'complex' branching structure of [continuant], plus coronal place: [-anterior], and (2) they were not phonetically stimulable, a therapeutic consideration in working with a child who was very sensitive about speech correction. Similar factors eliminated /r/. This left the (very) marginally established /h/, /ŋ/, and /l/ as segmental target choices. Because /ŋ/ can only be a SFWW or SFWF target, it was not a

[6]Marginally established syllable/word positions remain underspecified in comparison to other syllable/word positions for the features of a language. For example, at one point in development, coronal fricatives may be licensed for realization in SFWF position, but not in SIWI position or clusters. Development does not entail learning the feature composition of coronal fricatives, but the strengthening of the system's syllable positions by the realization of more segments within those positions.

[7]The coronal stops were treated undifferentially as the flap [ɾ], and were considered sufficiently robust as SIWI segments to become prosodic level realization targets.

choice, because such a choice would have resulted in major overlap with the prosodic condition. Thus /h/ (as a laryngeal node [+continuant] segment), and /l/ (as the underspecified {+consonantal]/[+sonorant] liquid) became segmental targets.

For both targets, substitution types were partially similar, since /ʔ/ appeared four out of 11 times as a non-match for /l/ (otherwise [w] appeared for /l/) and always for /h/. Whether [ʔ] was a default phonetic vowel onset, i.e. denoting a missing root node, or a phonemic laryngeal default substitution could not be determined. In either case, for /l/, at least root node feature [+sonorant] would need to be specified, and, if [ʔ] was a phonetic default, then [+consonantal] would also need to be specified. The fact that most substitutions were [w], seemed to indicate that [+consonantal] was not specified for /l/. The *labial place* rather than default coronal place (i.e. [j] as a substitution) may have indicated some underlying neutralization between /l/ and /r/, thus suggesting another reason to establish /l/ as a non-labial liquid.

Results of block 1 intervention

Prosodic tier

Changes in syllable and word structure improved *S3*'s conversational intelligibility dramatically. The average gain for trained syllabic targets was 60·75% (SD 9·85%) from the initial assessment probe. For skeletal slot marking (i.e. specification of CV*C* and CV*CV*), the average gain was 39·84% (SD 10·06%). Generalization of trained to untrained targets in conversation occurred within the prosodic sub-block, i.e. within 3 weeks of intervention. The SFWF [s] adjunction was eliminated in all but seven tokens, and completely for CVC targets.

CVC became established as a basic word shape with 90/98 [91·84%] matches (excluding SFWF liquids). The generalization to targets other than SFWF /p/ show that prosodic development was occurring, rather than just the learning of a specific segment. The most predictable generalization was SFWF/f/(100%). Since there was already an underspecified continuant obstruent [s] in SFWF position, the training of the labial /p/ facilitated the transfer to /f/. Other predictable generalizations were within the voiceless stop category.

C_1VC_2V became established as a basic word shape (14/20 [70%]). Overall, there were 35/41 (85·37%) CVCV matches. Again, generalization to targets other than the trained ones indicates that syllable development was occurring. Most improved untrained segments were /f/, /k/ and /g/. The stops were predictable from the work on the /t/ and /d/, and the /f/ was possibly predictable as a transfer from SIWW /p/, which was reasonably well established at the initial assessment.

Disyllabic targets were realized as such 127/134 (94·78%) times. The most frequently matching disyllabic target with one closed syllable was the CV.CVC word shape. The most complex of the disyllabic child forms was CVVC.CVC.

Two-element cluster production was beginning, with 5/89 (5·61%) onset clusters produced (with [fw] and [sn]) and four final nasal-stop clusters produced (as mismatches for singletons).

Segmental tier

In comparison, the average gain for trained segmental targets was 13·53% (SD 12·27%) with minimal change in matches for untrained segmental targets (see below).

A 22·2% proportional gain in matches appeared for SIWI /h/ to 6/19 (31·8%) matches. As on the initial assessment probe, *S3* produced two matching tokens of /l/. The slight proportional gain in matches (4·85%) was spurious, since there were fewer total tokens (11 rather than the 13 of the initial assessment probe). All non-matches for /l/ were [ʔ], which could be looked upon as a progressive rather than retrograde step, in that the labial glide [w] was no longer in use as a substitution.

Segmental changes for untrained targets

There was an increase in use of aspiration on SIWI/k/ and /t/ (i.e. [k^h] and [t^h]) and a slight decrease (3%) for /p/. The appearance of affricates (with their 'complex' structure) was a new development. This may have been another aspect of the changes in syllable shape, i.e. a structural change involving branching of a subsegmental constituent (feature [continuant]). (The coronal node feature [−anterior] was as yet unspecified for the alveopalatals.)

General comments

Prosodic and segmental tier autonomy

It was hypothesized that, if the prosodic and segmental/melodic levels of representation are psychologically real, then it should be possible to plan phonological intervention that focuses separately on the two levels. For each of the subjects in Bernhardt's (1990) and Von Bremen's (1990) studies, this was possible, as clearly demonstrated for *S3* above.

It was further hypothesized that, if the assumed dominance of the prosodic tier over the segmental is developmentally relevant, one might expect to find a different, possibly faster, rate of change for prosodic intervention than for segmental intervention. This appeared to be true for each of the subjects in Bernhardt (1990) and Von Bremen (1990), as it was in the example for *S3* described above.

Planning intervention in this way effected rapid change in prosodic development while allowing time for new articulatory gestures to be learned at the segmental level.

Underspecification

S3's overuse of SFWF [s] was an example of the interaction of a weakly established skeletal slot position with a minimally specified segment (coronal continuant). Other subjects in the studies also showed this kind of evidence of underspecification, as well as underspecification at the segmental level alone. This type of 'default' use has been described previously in the literature as use of 'favourite' sounds (e.g. as described in Edwards and Shriberg, 1983). Rather than ascribe a cognitive preference to children, the underspecification model in fact predicts that defaults are inevitable in the learning process.

Conclusion

A basic knowledge of linguistic theory is an essential prerequisite for sound clinical practice in speech–language pathology. Staying current with changes in theory continues to motivate change in assessment methodology and intervention approaches. That speech–language pathology has today an emerging base of linguistic theory is in no small part attributable to the profound insight, interest and actions of Emeritus Professor David Crystal, in the field of child language and its disorders. We dedicate this chapter to his immeasurable contributions to the field.

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Particular thanks go to the children and their families, who participated so energetically during the phonology projects. We express our gratitude to Dr Carolyn Johnson and Dr Patricia Shaw, of the University of British Columbia, for direction and guidance in the work of Bernhardt (1990) and Von Bremen (1990). Preparation of this chapter was supported in part by the B.C. Medical Services Foundation.

Appendix: Marked consonant specifications for adult English[a]

Segment	Root node	Laryngeal node	Place node
/m/	[+consonantal], [+nasal]		labial
/n/	[+consonantal], [+nasal]		
[ŋ]	[+consonantal], [+nasal]		dorsal[b]
/p/[c]	[+consonantal]		labial
/b/	[+consonantal]	[+voice]	labial
/t/[c]	[+consonantal][d]		
/d/	[+consonantal]	[+voice]	
/k/[c]	[+consonantal]		dorsal
/g/	[+consonantal]	[+voice]	dorsal
/f/	[+consonantal] [+continuant]		labial
/v/	[+consonantal], [+continuant]	[+voice]	labial
/θ/	[+consonantal], [+continuant]		coronal: [+distributed]
/ð/	[+consonantal], [+continuant]	[+voice]	coronal: [+distributed]
/s/	[+consonantal], [+continuant]		
/z/	[+consonantal], [+continuant]	[+voice]	
/ʃ/	[+consonantal], [+continuant]		coronal: [−anterior]
/ʒ/	[+consonantal], [+continuant]	[+voice]	coronal: [−anterior]
/ʧ/	[+consonantal]		coronal: [−anterior]; (complex)[e]
/ʤ/	[+consonantal]	[+voice]	coronal: [−anterior]; (complex)[e]
/w/	[+sonorant][f]		labial
/h/	[+consonantal][+continuant]	Laryngeal node	
/j/	[+sonorant]		
/l/	[+consonantal], [+sonorant]		
/r/	[+consonantal], [sonorant]		coronal: [+distributed][g]

[a]The above encodings and feature hierarchy presented in Fig. 2 are derived from Sagey (1986). In addition, [+distributed] is used to distinguish interdentals from alveolars, and /r/ from /l/. 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.
[g]There is a possibility that a redundant feature available at a later stage of derivation—labial [+round]—becomes realized at the surface when the major features of /r/ are unrealized, allowing surfacing of [w], or that /r/ has both a labial and coronal place node.

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