PHONOLOGICAL DISORDERS IN ENGLISH SPEAKING CHILDREN: A NONLINEAR ANALYSIS

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PHONOLOGICAL DISORDERS IN ENGLISH SPEAKING CHILDREN: A NONLINEAR ANALYSIS

by

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Abstract

Children with phonological disorders have difficulty acquiring some of the sound contrasts of their language, and this results in unintelligible speech. In the present study the speech of two children with phonological disorders is analyzed using a nonlinear phonological framework. Nonlinear phonology allows for the independent analysis of segmental and prosodic impairments that are commonly found among phonologically disordered children, while at the same time it allows for an analysis of phonological problems resulting from the interaction of the segmental and prosodic tiers.

The data demonstrates that segmental and prosodic acquisition occur independently, although some tier interaction is also evident. Segments with a complex structure are acquired later than segments with a simple structure; as well, features found higher in the geometry are acquired before more deeply embedded features. Unmarked syllable and word templates are acquired before those with a more marked structure, such as those with complex onset and coda consonants. This study argues that children with phonological disorders show an acquisition sequence that proceeds along the same path as for children with normally developing phonological systems, but that acquisition occurs at a slower rate for the former group. Furthermore, the present study demonstrates the significance of the nonlinear approach to the analysis of phonologically disordered speech.

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1.0 Introduction

In this study the phonological systems of two phonologically disordered children are analyzed. One child is a 9;0 year-old male (Graham) and the other is a 3;4 year-old female (Stacy). The data from Graham was published in Grunwell & Yavas (1988) and the data from Stacy was published in Miccio & Elbert (1996). In the present study their data were reanalyzed using nonlinear phonology, a framework that has recently been applied to phonological acquisition as well as to the assessment and treatment of phonological disorders. One of the advantages of this framework is that it allows for independent analysis of segmental and prosodic information.

In this study a phonetic inventory and an inventory of syllable and word templates are compiled for each child and these inventories are analyzed using nonlinear phonology. As well, an analysis is carried out across segmental and prosodic tiers. The children's inventories are compared to fully developed adult inventories of English. In addition, the children's phonological repertoires are examined in order to determine how or if they deviate from typical patterns of phonological development.

1.1 Purpose and Significance of the Study

The purpose of the study is to demonstrate the usefulness of the nonlinear framework in accounting for phonologically disordered speech. Linguistic theory has had a significant impact on the analysis and treatment of phonologically disordered systems. As noted by Bernhardt & Stoel-Gammon (1994, p.124), prior to the application of phonological theory to the field of speech-language pathology a 'phoneme-by-phoneme' approach was used to analyze deviant speech patterns. For example, clinicians would observe that a child may substitute [b] for /v/, [t] for /s/, and [d] for /z/. Each error would be analyzed independently, sometimes missing broader generalizations, for example, that the child has an error pattern in which fricatives are replaced by stops. Additionally, the possibility that correcting one of these errors would generalize across the error pattern was not considered; as a result, treatment was implemented in isolation for each error in the child's speech. Although the term 'stopping' was used to capture such generalizations, it was not until the advent of distinctive feature theory that the term gained a formal distinctive status and characterization.

According to Bernhardt & Stoel-Gammon (1994, p.124) linguistic theory was first applied to speech-language pathology in the early 1970s through the adoption of the distinctive feature framework (cf. Compton, 1970; Oller, 1973). During this period, clinicians began to recognize that segments were composed of features and to analyze deviant speech patterns according to which features were present or absent in a child's inventory. When treating phonological disorders, speech-language pathologists aimed to target features rather than whole segments with the expectation that, once a feature was incorporated into a child's inventory, it would generalize to all segments that contain that feature (cf. Costello & Onstine, 1976; McReynolds & Bennet, 1972; McReynolds & Engmann, 1975). As pointed out by Bernhardt & Stoel-Gammon (1994, p.124), one of the problems with this approach is that fact that there are several versions of the distinctive feature framework (Chomsky & Halle, 1968; Jakobson, Fant, & Halle, 1963; Singh, 1976) and there was little consensus as to which version should be adopted.

Furthermore, this framework only considers the non-prosodic aspect of phonological disorders; this can be problematic, since children with phonologically disordered speech often encounter difficulties beyond the segmental inventory, such as problems with syllable structure, stress patterns, and intonation (collectively termed "prosody").

Bernhardt & Stoel-Gammon (1994, p.124) report that another phonological theory that has received extensive attention in the field of speech-language pathology is Stampe's Natural Phonology (Stampe, 1969; 1973). According to this theory, children have an innate set of phonological processes which must be unlearned if they are not applicable to the language being acquired by the child. In treatment procedures, speech-language pathologists aimed to eliminate the phonological processes that are not relevant for the language being acquired. For example, a clinician would observe that a child might front all velar consonants. If a child could learn through treatment to produce /k/ correctly, it was predicted by this theory that the process of velar fronting would also be eliminated or unlearned in the production of /g/ and /ŋ/. Bernhardt & Stoel-Gammon (1994, p.125) discuss several weaknesses of this theory. First, they note that process analysis focuses only on output errors and therefore does not provide an adequate representation of the child's phonological system; it does not take into account the fact that the child may have problems beyond production. The theory is also problematic in that it suggests that phonological acquisition is an eliminatory process; it assumes that initially, children have a complex system which must be simplified by turning off the phonological processes which are not found in the language being acquired.

Recently, nonlinear phonology has been used in the assessment and remediation of phonological disorders (cf. Bernhardt, 1992a,b; Bernhardt & Gilbert, 1992; Bernhardt & Stoel-Gammon, 1994; Chin & Dinnsen, 1991; Dinnsen & Chin, 1995; Schwartz, 1992; Yavas, 1994). In this approach children's deviant phonological systems are described in terms of both segmental and prosodic levels of representation. The adoption of this approach in the analysis of phonologically disordered systems has several advantages. According to Bernhardt (1992b, p. 306) the nonlinear approach provides a more complete description of the child's phonological representation, as compared to the models discussed above. The number of rules required to describe the system is reduced and, furthermore, rules are replaced by enriched representations (Bernhardt, 1992a, p. 261). Also, as noted by Bernhardt & Stoel-Gammon (1994, pp. 140-141) nonlinear phonology allows for the independent analysis of prosodic and segmental tiers. The framework also considers how the tiers interact. As a result, deficiencies at different levels of the phonological representation can be identified.

This has important clinical implications. For example, if a child has delayed prosodic structure and minimal segmental difficulties, an intervention protocol can be constructed to target the prosodic tier independent of the segmental tier by focusing on the development of syllable shapes that are not present in the child's inventory. Alternatively, treatment goals can be established which concentrate on tier interaction by targeting, for example, segments in certain syllable or word positions. By targeting prosodic and segmental tiers independently, development on one or the other tier can lead to advancement of the child's phonological system.

Any phonological theory must address the learnability problem; a theory must be able to explain the development of the child's phonological system of the language being acquired. Given the fact that phonologically disordered children are similar in some respects to children with normally developing phonological systems (Leonard, 1992, p. 499), phonological theories must also be able to address the issue of atypical phonological development. Thus the present study may also have important implications for the nonlinear phonological framework. If nonlinear phonology is able to provide explanatory adequacy, it can be useful in the analysis and treatment of disordered phonological systems.

1.2 Phonological Disorders

1.2.1 Characteristics

Children who are phonologically disordered usually have no apparent organic pathologies that would hinder the normal development of speech (Grunwell, 1991, p.41). These children, who can be confidently diagnosed by the age of 4;0, have an extensive vocabulary and are able to comprehend spoken language. They also have the ability to produce lengthy utterances that appear to be grammatically correct and are spoken in the proper context. Furthermore, they do not appear to have any intellectual disabilities. However, children with phonological disorders may have difficulty in acquiring some of the contrasts between the sounds of their language which are used to signal differences in meaning (Leonard, 1992, p. 499); this can result in unintelligible speech (Leinonen, 1991, p. 121).

There are several characteristics commonly found in the speech of phonologically disordered children which are summarized by Stoel-Gammon (1991, pp. 28-29). First, children with phonological disorders use a restricted set of sounds. Common segmental inventories include stops (/p,t,k,b,d,g/), nasals (/m,n,ŋ/) glides (/w,j/), and a small inventory of vowels. Such inventories are also common among normally developing children at a very early age. Although children with normally developing phonological systems have usually added fricatives and liquids to their inventories by the age of 2;0, phonologically disordered children develop these more complex segments at a much later age. A segment is said to be more complex when it has a more elaborate structure (Rice, 1992, p. 64). The notion of segmental complexity is discussed further in section 2.1.4.

Stoel-Gammon (1991, p. 28) observes that children with phonological disorders also produce limited word templates and syllable shapes; the common syllable types are a single vowel (V) and a consonant plus a vowel (CV). Bisyllabic words are restricted to CVCV shapes, which are often the result of the reduplication of a single syllable. These syllable shapes are commonly found in the inventories of younger children with normal phonological development.

Chronological mismatch is common in the speech of phonologically disordered children (Stoel-Gammon, 1991). Chronological mismatch is a phenomenon whereby the system is "advanced in some respects and severely delayed in others"(p. 28). This occurs when one area of phonological development advances to the point where erroneous productions have disappeared, while another area remains severely delayed due to the production of age-inappropriate errors resulting in a phonological system that is unbalanced.

Another distinguishing feature in the speech of phonologically disordered children is the production of unusual error types (Stoel-Gammon, 1991, p. 29). Such error types are rare in the speech of normally developing children, and when they are found they have a short duration. Examples of such error patterns include atypical substitution and deletion patterns, the use of sounds not found in the language being acquired, and unusual vowel patterns.

Variability in the realization of segments is common in the speech of normally developing children (Stoel-Gammon, 1991, p. 29). Variability occurs as a result of the reorganizing of phonological systems when new contrasts are acquired; there is a gradual improvement in accuracy as children begin to substitute newly acquired forms for previous erroneous productions. Conversely, in the speech of children with disordered phonological systems variability seems to occur without any apparent acquisition of correct forms.

In the speech of phonologically disordered children, phonological acquisition is not as advanced as grammatical learning (Grunwell, 1991, p. 44). The systems do not exploit all of the feature combinations that the children are capable of producing, even though the contrasts are necessary to signal meaning differences. Systematic sound preferences are common among some phonologically disordered children (Grunwell, 1991, p. 45). This occurs when one segment is used for a variety of target sounds.

1.2.2 Phonological processes in disordered phonology

Several phonological processes are often found in the speech of phonologically disordered children (Hodson & Paden, 1991).

1.2.2.1 Omission of segments and consonant clusters

Processes involving the omission of segments include the deletion of single consonants and the simplification of consonant clusters (Hodson & Paden, 1991). Example (1) illustrates the deletion of a single consonant in word final position:

(1) dog [d ɔ] [H&P, p. 39]

Children use several strategies to reduce consonant clusters; strategies include coalescence, migration and epenthesis (Hodson & Paden, 1991, p. 39). Coalescence is the replacement of two sequential consonants by a single consonant that shares some features of the original consonants in the cluster. With coalescence, the child is demonstrating the awareness that there are two sounds, but is unable to pronounce the cluster. Coalescence is exemplified in (2), where the sequence /sp/ is replaced by /f/, which shares features with /s/ and /p/:

(2) spoon [fun] [H&P, p. 40]

Migration is the movement of one of the consonants in the cluster to another word position, as shown in (3):

(3) smoke [moks] [H&P, p. 40]

Finally, vowel epenthesis is the insertion of a vowel to break up the sequence of consonants, as shown in example (4):

(4) black [bəlæk] [H&P, p.41]

1.2.2.2 Syllable structure alterations

Syllable structure alterations are common in the speech of phonologically disordered children (Hodson & Paden, 1991). It should be noted that the syllable alterations discussed by Hodson & Paden actually involve foot structure since unstressed syllables are involved. One such alteration is the deletion of an unstressed syllable, as shown in the next example:

(5) probably [prabli] [H&P, p.36]

1.2.2.3 Glottal replacement

It is also common for phonologically disordered children to substitute a glottal stop for a segment they are unable to produce (Hodson & Paden, 1991). This is demonstrated in (6):

(6) hat [hæʔ] [H&P, p.41]

1.2.2.4 Substitutions

The substitution of one segment for another is a common mechanism employed by children with phonological disorders (Hodson & Paden, 1991). These substitution processes lead to changes in place of articulation, manner of articulation, and voicing of the target segment. Examples of substitutions causing changes in place of articulation of the consonant are shown in (7), where the consonant is fronted, and in (8) which is a case of depalatalization and fronting:

(7) key [ti] [H&P, p. 42]

(8) shoe [su] [H&P, p. 43]

An example of a substitution causing a change in the manner of articulation of the consonant is given in (9) which is a case of gliding which is the replacement of /l/ or /r/ by /w/ or /y/.

(9) red [wɛd] [H&P, p.44]

Finally, substitution processes also include changes in the voicing features of a segment. An example is prevocalic voicing, as in (10):

(10) two [du] [H&P, p. 45]

1.2.2.5 Vowel alterations

Vowel substitutions, such as vowel neutralization, are also common in the speech of phonologically disordered children (Hodson & Paden, 1991). Vowel neutralization limits the inventory of vowel contrasts. Sometimes only a few specific vowels are neutralized. An example of vowel neutralization is given in (11). In this example, two words that contrast in the underlying representation are pronounced identically:

(11) bed; bad [bʌd] [H&P, p. 46]

1.2.2.6 Context-related alterations

Context related alterations include processes such as assimilation and reduplication (Hodson & Paden, 1991). In assimilation, the segment adopts the characteristics or features of a neighboring segment. (12) illustrates a case of labial assimilation, while nasal assimilation in shown in (13). These examples demonstrate consonant harmony, a case of non-local assimilation.

(12) pin [pɪm̲] (H&P, p. 47)

(13) thumb [n̲ʌm] (H&P, p.47)

Reduplication, another context related alteration, is demonstrated in the following example. Reduplication involves copying a portion of a word (O'Grady & Dobrovolsky, 1996, p. 121).

(14) basket [bæbæ] (H&P, p. 48)

1.2.2.7 Nonphonemic alterations

Nonphonemic alterations occur when a sound is consistently produced in error but is still recognizable as the target phoneme (Hodson & Paden, pp. 48-50). Examples include consonants produced with tongue protrusion, whereby the tongue tip is positioned forward during the production of consonants (/t/ → [t̪]), lateralization, which involves emission of a sound to the sides rather than centrally (/s/ → [ɬ]), and nasalization, which is the lowering of the velum during the production of normally nonnasal sounds (/sa/ → [s̃ã]).

1.2.2.8 Sound class deficiencies

Some of the phonological processes common in the speech of phonologically disordered children result in systematic alterations of entire classes of sounds. Following is a discussion of the possible sound class alterations (Hodson & Paden, 1991, pp. 50-3). However, it should be noted that phonologically disordered children vary in terms of which sounds are produced deficiently.

Among the obstruents affected are the class of strident sounds /f, v, s, z, ʃ, ʒ, ʧ, ʤ/ (Hodson & Paden, 1991). These sounds are seldom produced properly by phonologically disordered children. The sounds are subject to processes such as deletion (15) and substitution (16):

(15) fish [fɪ] (hypothetical example)

(16) soap [hop] (H&P, p. 51)

According to Hodson & Paden, other obstruents which are often pronounced in error by phonologically disordered children are the posterior obstruents /k, g/ and the glottal fricative /h/. These are often omitted, as exemplified in (17), or assimilated to an alveolar segment, as in (18):

(17) bike [baɪ] (H&P, p. 52)

(18) cat [tæt] (H&P, p. 52)

Finally, the anterior non-strident obstruents, which include the labial /p,b/ and alveolar /t,d/ stops and the interdental fricatives /θ, ð /, are often altered by phonologically disordered children. The stops are commonly deleted in word final position (19) and the interdental fricatives are often replaced by a stop, as in (20):

(19) boat [bo] (H&P, p. 52)

(20) this [d̲ɪs] (H&P, p.52)

Within the class of sonorants, liquids are treated differently according to where they occur in the word or syllable. Prevocalic liquids often undergo gliding (defined earlier), as in (21), or they are deleted when they are a part of a consonant cluster, as in example (22):

(21) run [w̲ʌn] (H&P, p.52)

(22) slow [so] (H&P, p.53)

On the other hand postvocalic liquids are either omitted (23) or replaced by a vowel (24) (Hodson & Paden, 1991, p. 53). Glides are often deleted (25), replaced by a stop (26), or undergo depalatalization (27), and nasals are commonly deleted in word final position (28) or replaced by a stop (29) in the speech of phonologically disordered children. (Examples (23)-(29) are hypothetical):

(23) 'ball' [ba]

(24) 'cable' [kebʊ˞]

(25) 'yes' [ɛs]

(26) 'yoyo' [dodo]

(27) 'yes' [wɛs]

(28) 'can' [kæ̃]

(29) 'gum' [gʌb]

1.3 Typical Versus Atypical Phonological Development

Children with phonological disorders are in some respects similar to younger normally developing children while differing in certain other aspects of their phonological development (Leonard, 1992, pp. 496-99). The error patterns most commonly found in the speech of phonologically disordered children are also well documented in the speech of normally developing younger children. These errors include consonant deletion, consonant cluster reduction, stopping, and gliding. Also, in both typical and atypical phonological development, errors seem to be influenced by the phonetic characteristics of the segment being acquired and the plausible substitutes for that segment in the language being acquired.

There are two important differences between phonologically disordered children and normally developing children (Leonard, 1992, p. 497-498). The most significant is that children with phonological disorders have unusual error patterns. An example is the replacement of an earlier developing sound, such as /b/, with a presumably later developing sound, such as /v/, or the use of a sound which does not occur in the language being acquired, such as the use of a bilabial fricative [β] in English which does not have this segment. In addition, phonologically disordered children often add a sound in a place where it does not belong. Some of these error patterns may be found in the speech of younger normally developing children; however, these patterns are found more frequently and less systematically in the speech of phonologically disordered children. Another difference relates to the difference in the vocabularies of phonologically disordered children and other children with similar phonological inventories. Phonologically disordered children have phonological inventories similar to younger children with normal phonological development. However, since the former group usually have no delay in other aspects of their language development, they have much larger vocabularies compared to the latter group.

1.4 Models of Phonological Development

Models of phonological development must be able to account for both typical and atypical acquisition. Leonard (1992, p. 500-506) discusses three models of phonological development and their capabilities to account for phonological disorders.

The first model is the interactive-activation model proposed by Stemberger (1987) which posits interaction between different levels of linguistic representation via feedforward and feedback mechanisms. According to this model, language processing begins at deeper linguistic levels and proceeds to more surface levels. The linguistic levels recognized by this model are shown in the following diagram:

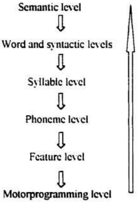


Figure 1. Interactive-Activation Model (after Leonard, 1992).

In Figure 1 the arrows pointing downward illustrate that processing begins at the semantic level and information from deeper levels is fed forward to more surface linguistic levels. The arrow pointing upward illustrates the fact that there is also a possibility of a feedback mechanism at work whereby information from more surface levels can have an effect on deeper level processing by feeding information back to, and thereby activating, deeper levels. According to this model, in phonologically disordered children feedback to deeper linguistic levels is much greater than in normally developing children, causing a greater and longer lasting effect on the child's phonology. As a result, the deeper levels have phonological representations which are similar to surface level representations. For example, consider a child who cannot produce the final consonant of a CVC template. At the motor programming level, the child will produce a CV syllable shape and will feed back to the syllable level the information that final consonants cannot be produced. This influences processing at the deeper syllable level and the prevalent syllable shape becomes CV. This misinformation leads to "gang effects" whereby the child produces words that conform to the CV syllable shape, regardless of the adult form. Feedback can also result in variability, as the child may have several syllable templates available and any word may conform to various templates at different times. Alternatively, a word may be a combination of the available syllable templates. In summary, while there are more details, the general idea of this model is that excessive feedback is the cause of the delayed phonological development.

Another model is the adult-like representation model which was initially proposed by Smith (1973). According to this model, the child has an underlying representation that approximates the adult form. During the course of production, the child applies various rules to this form, such as weak syllable deletion or assimilation rules that result in an output form that can deviate from the target. This model predicts variability in production as the application of different rules cause variable realizations of the same form. This model is no longer considered to accurately account for phonological development as it assumes that children begin with a fully developed underlying adult phonology. This theory does not account for how a child's phonological system develops or matures over time, as it suggests that children begin with the adult underlying representation already in place.

Finally, in Menn's (1983) two-lexicon model of phonological development, a child has his or her own input lexicon and a set of rules that relate it to the output lexicon. According to this model, the child's output will be one of the canonical forms s/he has available. For example, consider the child's pronunciation of the word 'kiss'. Rules operate on the input and specify the canonical form. The child may produce a C + V shape whereby the consonant must be a velar and the vowel must be [+high]. This results in the production of [kɪ]. Alternatively, the child may also have a specification of a canonical form of [d] + V + [s] with [+high] specified for the vowel, resulting in the production of [dɪs]. This model appears to yield output results similar to the Interactive Activation Model where the output depends on the syllable templates available to the child. In short, the main idea of the two-lexicon model is that input and output representations are separate and both can be non-adult-like. For a further discussion of the abandonment of this model, see Ferguson et. al. (1992).

Grundy (1989, pp. 256-258) also discusses several models of deviant phonological development. She states that children with normally developing phonological systems go through a series of developmental stages until the target pronunciation of sound patterns is attained and that children with phonological disorders do not progress through the same developmental stages. She suggests that the errors produced by phonologically disordered children may the be result of one or some combination of the following factors: (i) a purely motor- programming problem where the child correctly stores the input, but there is a faulty connection to the speech production mechanisms, yielding faulty productions; (ii) motor programming immaturity, whereby the sound sequences are beyond the child's production capabilities and, as a result, a simpler sequence is produced; (iii) a deep perceptive problem, whereby the child perceives the input erroneously; or (iv) a deep organizational problem in which the child perceives the input correctly but it does not fit into the child's current underlying representations and therefore the input is stored with an incorrect underlying representation. This hypothesis seems to be comparable to Leonard's Interactive-Activation model where input forms are accommodated to fit phonological information which the child already has formed. The example used above to illustrate Leonard's model was that a child may hear a CVC syllable but does not have this template in his or her underlying representation. As a result, it is stored as a template that already exists, such as CV. This example is consistent with Grundy's theory that the form is perceived correctly but is stored incorrectly because it does not fit the child's underlying representation. Grundy (1989, p. 258) notes that the problem may not be as clear cut as these explanations suggest, but instead may be the result of some combination of productive, perceptual and organizational problems.

Bernhardt (1992a) proposes that children come to the language learning process with an innate syllable template as well as a predetermined feature geometry and that language-particular representations must be learned. The fact that there are separate tiers in a representation (prosodic versus segmental) implies that children can learn or elaborate the final representations on each tier independently. The use of hierarchical relationships implies that elements higher in the structure will be acquired before those that are more deeply embedded. For example, Bernhardt (1992b, p. 309), in applying nonlinear phonology to intervention with a phonologically disordered child, hypothesized that since the prosodic tier is higher in the phonological representation than the segmental tier, treatment should proceed at a faster rate at the prosodic level than at the segmental level. This hypothesis was found to be valid. Within the segmental tier, features that define segments as a consonant or a vowel (root-node features) should be acquired before place features, since they are higher in the geometry.

Rice and Avery (1995, p. 35-36) suggest that children begin phonological acquisition with an impoverished feature tree. That is, the underlying feature tree is initially lacking in specification. This results in children having a wide range of possible realizations for any particular segment. These feature trees become more sophisticated with positive evidence from the environment. As more contrasts are required in a child's inventory, more feature contrasts are acquired. This is known as tree-building. This view may be contrasted with tree-pruning, whereby a child's feature geometry tree has more structure present than required by the native language. With exposure to the language environment the features that are not required are eliminated from the underlying representation.

Working within a nonlinear framework, Bernhardt & Stoel-Gammon (1994, p. 132) adopt a 'filter' model of phonological acquisition. They assume that children come to the language learning situation with an underdeveloped representational framework already in place, which can be viewed as a passive filter. When children receive input that agrees with their representation, it passes through the filter and is encoded. However, when input information does not agree with the representational framework, it does not pass through the filter. For example, a child may hear an adult say the word 'dog'. Although the adult form has a CVC syllable template, the child may not have acquired syllables with coda consonants. Therefore, the CVC shape does not agree with the child's representation; thus, the final consonant is not perceived. Such input information will not be encoded until such a time when the child's system matures to a point where it is able to represent information that is equivalent in complexity to the input information from the surrounding language, and until the child has had significant exposure to the input, and is, thus, forced to recognize it.

The adoption of this filter representation suggests that the development of a phonological system is a progressive process (Bernhardt & Stoel-Gammon, 1994, p. 132). Perceptual development often precedes productive development. In this light, it is possible that, although children may perceive some of the adult phonological phenomena, they may not be able to produce it. This accounts for some of the errors made by very young children, or by children with delayed phonological systems.

It is also possible that children may be producing two contrasting segments but not producing enough of a phonetic difference between them that this difference is perceived by the listener. This phenomenon is known as "covert contrast." Children sometimes produce phonetic distinctions that adults cannot hear, and this can only be determined by spectral analysis (Crystal, 1987, p. 40). For example, to the adult ear, a child may not appear to be distinguishing between the segments /s/ and /ʃ/; they may both "sound like" [s]. Spectral analysis sometimes reveals that there is indeed a difference in how these two segments are being produced. At first glance, it may appear that a child has not acquired a phonemic opposition, but spectral analysis may reveal that acquisition of this opposition is in progress.

The filter theory is comparable to the interaction-activation model discussed by Leonard (1992, pp. 500-503) in which interaction occurs between linguistic levels due to feed forward and feedback. For example, with Bernhardt & Stoel-Gammon's (1994) theory, interaction occurs between tiers that correspond to linguistic levels in Leonard's theory. In Bernhardt and Stoel-Gammon's filter model, a child may hear a word with a CVC syllable shape, but only have the representation for CV syllables. Therefore, such a word will not pass unchanged through the filter and may be produced as a CV shaped word. Similarly, in Leonard's model, CVC may not be encoded as a template and the child will alter the form to fit a template that already exists. Like Leonard's model, the filter model of Bernhardt & Stoel-Gammon (1994) is not comparable to the adult-like model (Leonard, 1992, pp. 503-505), since the child's representation is not necessarily a close approximation of the adult representation of the target language.

1.5 Conclusion

Various phonological frameworks have been adopted by researchers and clinicians in the analysis and treatment of deviant speech patterns. Many of these theories, such as distinctive feature theory and Natural Phonology, fail to provide an adequate description and treatment protocol for phonologically disordered speech. Current trends favor the idea that child representations are immature, as opposed to adult-like. Psycholinguistic theories have also introduced models with feedback mechanisms, where traditional phonological theory has only feed-forward models. The nonlinear framework has the potential to provide a more accurate description of normal and deviant speech, and has recently been introduced in the analysis and treatment of phonological disorders. In the present study nonlinear phonology is used as a tool to account for atypical phonological acquisition.

2.0 Assumptions in the Literature

2.1 Nonlinear Phonology

Nonlinear phonology differs from other phonological frameworks by focusing on hierarchical organization among phonological units such as words, syllables, segments, and features. Separate hierarchical levels of organization, called tiers, are posited for prosodic and segmental information (Bernhardt & Stoel-Gammon, 1994).

The prosodic levels include morae (μ), syllables (σ), feet (F), prosodic words (ω), the prosodic phrase (ϕ), and the intonational phrase (IP). This hierarchy is shown in Figure 2:

IP (intonational phrase)
|
ϕ (prosodic phrase)
|
ω (Prosodic word)
|
F (feet)
|
σ (syllable)
|
μ (mora)

Figure 2. The prosodic hierarchy (after Inkelas & Zec, 1995, p. 538).

Below the mora is the non-prosodic level of the segment. In many feature geometry models the root node acts as a link between the prosodic and segmental tiers (Bernhardt, 1992a, pp. 269-270). Features are grouped together under organizing nodes.
Figure 3 shows the feature geometry posited by Clements & Hume (1995, p. 292) which is adopted in this paper:

Consonants

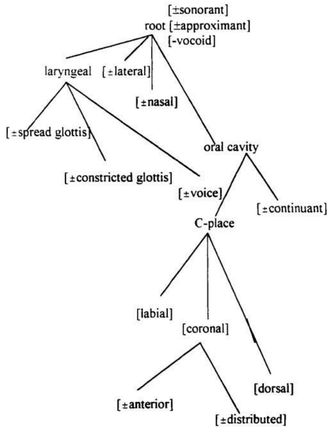


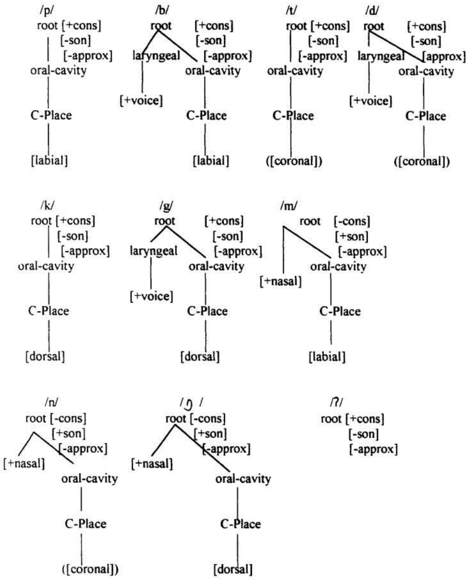
Figure 3. Feature geometry for consonants (Clements & Hume, 1995, p. 292).

In Figure 3, the segment represented is a consonant. The root node dominates all other nodes and all of the features in the geometry. The root node bears the major class features [sonorant], [approximant], and [vocoid]. The features dominated by the root node define a segment as a sonorant, obstruent, nasal, liquid or vocoid (glide/vowel). The root node also helps define the manner of articulation of segments. The laryngeal node dominates the features that define the obstruent voicing and glottal characteristics of the segment. Clements & Hume (1995, pp. 271-273) posit an oral cavity node intervening between the root and place nodes that dominates the place node and the [±continuant] node. This model also posits separate C-place and V-place nodes for consonant and vowel place features respectively. Table 1, modified from O'Grady and Dobrovolsky (1996, p.31), summarizes the place and manner of articulation of English consonants and the features for each segment:

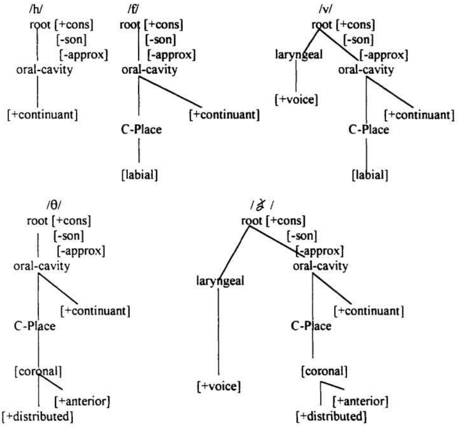
Table 1. Manner of Articulation of English Consonants. (All are [-voicoid]).

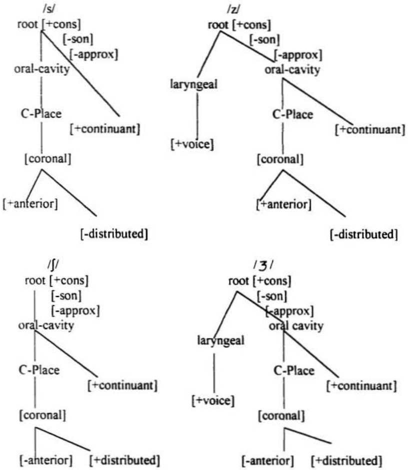
					[+dis]	[-dis]			
					[+ant]	[+ant]	[-ant]		
			[lab]	[lab]	[cor]	[cor]	[cor]	[dors]	
			Labial	Labio-dental	Inter-dental	Alveo Lar	Alveo-palatal	Velar	Glottal
[+cons] [-son] [-approx]	[-cont] [-voice] [+voice]	Stop Voiceless Voiced	p b			t d		k g	ʔ
[+cons] [-son] [-approx]	[+cont] [-voice] [+voice]	Fricative Voiceless Voiced		f v	θ ð	s z	ʃ ʒ		h
[+cons] [-son] [-approx]	[+cont][-cont] [-voice] [+voice]	Affricate Voiceless Voiced					ʧ ʤ		
[+cons] [+son] [-approx]	[+nasal] ([+voice]) [-cont]	Nasal voiced	m			n		ŋ	
[+cons] [+son] [-approx]	[+lateral] [-lateral]	Liquid Lateral central				l r			
[+son] [+approx]	[+voice] [+cont]	Glide Voiced Voiceless	w				j		

Figure 4 illustrates the adult English underlying representations for each of the segments in Table 1, assuming the use of underspecification discussed in section 2.1.2. The underlying representations shown below are modified from Bernhardt & Stoel-Gammon (1994, p.129). Features appearing in parentheses are default features (to be discussed below).



/p/
root [+cons]
[-son]
[-approx]
oral-cavity
C-Place
[labial]
/b/
root
[+cons]
[-son]
[-approx]
laryngeal
oral-cavity
[+voice]
C-Place
[labial]
/t/
root [+cons]
[-son]
[-approx]
oral-cavity
C-Place
([coronal])
/d/
root
[+cons]
[-son]
laryngeal
[approx]
oral-cavity
[+voice]
C-Place
([coronal])
/k/
root [+cons]
[-son]
[-approx]
oral-cavity
C-Place
[dorsal]
/g/
root
[+cons]
[-son]
laryngeal
[-approx]
oral-cavity
[+voice]
C-Place
[dorsal]
/m/
root
[-cons]
[+son]
[-approx]
oral-cavity
[+nasal]
C-Place
[labial]
/n/
root [-cons]
[+son]
[-approx]
[+nasal]
oral-cavity
C-Place
([coronal])
/ŋ /
root [-cons]
[+son]
[-approx]
[+nasal]
oral-cavity
C-Place
[dorsal]
/ʔ/
root [+cons]
[-son]
[-approx]


/h/
root [+cons]
[-son]
[-approx]
oral-cavity
[+continuant]
/f/
root [+cons]
[-son]
[-approx]
oral-cavity
[+continuant]
C-Place
[labial]
/v/
root [+cons]
[-son]
[-approx]
laryngeal
oral-cavity
[+voice]
[+continuant]
C-Place
[labial]
/θ/
root [+cons]
[-son]
[-approx]
oral-cavity
[+continuant]
C-Place
[coronal]
[+anterior]
[+distributed]
root [+cons]
[-son]
[-approx]
oral-cavity
laryngeal
[+continuant]
C-Place
[coronal]
[+voice]
[+anterior]
[+distributed]


/s/
root [+cons]
[-son]
[-approx]
oral-cavity
C-Place
[+continuant]
[coronal]
[+anterior]
[-distributed]
/z/
root [+cons]
[-son]
[-approx]
laryngeal
oral-cavity
C-Place
[+continuant]
[+voice]
[coronal]
[+anterior]
[-distributed]
/ʃ/
root [+cons]
[-son]
[-approx]
oral-cavity
C-Place
[+continuant]
[coronal]
[-anterior]
[+distributed]
/ʒ/
root [+cons]
[-son]
[-approx]
laryngeal
oral cavity
C-Place
[+continuant]
[+voice]
[coronal]
[-anterior]
[+distributed]

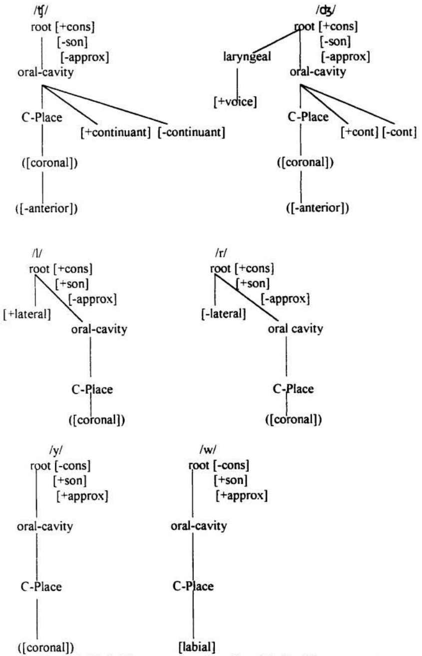


Figure 4. Underlying representations for adult English consonants.

Although vowels will not be discussed in the present study, the feature geometry for vocoids is shown in Figure 5:

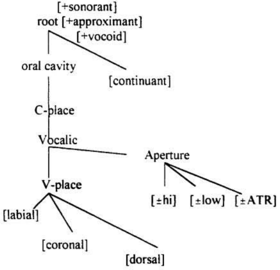


Figure 5. Feature geometry for vocoids (modified from Clements & Hume, 1995, p.292)

In Figure 5, a vocalic node depends from the C-place node, which in turn dominates the V-place and aperture nodes. The V-place node also dominates the features [labial], [coronal], and [dorsal] (vowel place features). The aperture node defines vowel height and the feature ATR refers to advanced tongue root.

2.1.1 Default [coronal]

Coronal is the universally unmarked default place of articulation (Bernhardt, 1992a, p. 510). There are several pieces of evidence to support that this is the case (Kenstowicz, 1994, pp. 516-521). First, coronal appears to be the most common place of articulation in human languages. Also, when neutralization processes occur, it appears that phonemes of other places of articulation tend to become coronals more often than coronals become labials or dorsals. In addition, when rules of epenthesis occur, coronal is a frequent place of articulation of the epenthetic consonant. Coronals combine with labials and velars or other coronals to form consonant clusters more often than consonants of other places of articulation. Finally, coronals undergo place assimilation more often than labials or velars.

The fact that coronal is the universally unmarked place of articulation can be described by assigning them the most minimal structure, namely a bare place node (Kenstowicz, 1994, p. 517). A default rule would then assign coronal to a bare place node at a late stage in the derivation if no other feature has been assigned via contextual spreading from another consonant:

$$\begin{array}{ccc} \text{Place} & \rightarrow & \text{Place} \\ & & | \\ & & \text{Coronal} \end{array}$$

Figure 6. Underlying and surface structure for coronal place of articulation (Kenstowicz, 1994, p. 507)

2.1.2 Underspecification

As indicated by the previous discussion of [coronal], models of feature geometry often assume that not all features are specified in the underlying representations. Redundant information is filled in via default rules (Kenstowicz, 1994, p. 517). Although there are opposing theories of underspecification (cf. Archangeli, 1984; Clements, 1988; Steriade, 1987) most agree that sonorants are underlyingly unspecified for [+voice] and coronals are underspecified for the [coronal] place feature. For a discussion of underspecification in child speech, see Stoel-Gammon & Stemberger (1993).

2.1.3 Acquisition of feature geometry

My assumption is that the order of acquisition of features is determined by their position in the feature geometry (Bernhardt, 1992a, p. 273): features at higher levels in the hierarchy will be acquired first; more deeply embedded features, such as those dominated by the place node, will be learned later.

I assume that children come to the language learning situation with a set of default, or universally unmarked, features. I also assume that children can only produce segments that can be realized with a minimal amount of structure, and that they have a small set of defaults that fill in the missing structure (Bernhardt, 1992a, p. 274). Input from the language being acquired confirms the presence of these default features and also provides positive evidence for the acquisition of more complex features. Sufficient input evidence for marked features results in the marked features being encoded as part of the underlying phonological representation of the target language (Bernhardt, 1992a, p. 274). Rice &

Avery (1995, p.35) provide an example of how development would proceed under the place node. The first distinction a child learns may be between coronal and non-coronal place. The child then develops the distinction between the coronal and labial place node. Finally, a three-way distinction is acquired and the child now differentiates between the coronal, labial and dorsal places of articulation.

Phonological analysis begins at around age 1;6 (Fee, 1995, p. 52). Previous to this time, during the acquisition of the first fifty words, children learn words as whole units. However, their vocabularies eventually become too large and some type of organizational system must intervene; it is at this time that phonological analysis begins.

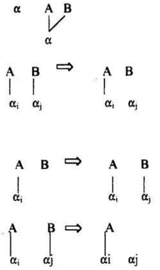
According to Fee (1995, p.50), following Archangeli and Pulleybank (1986) and Piggott (1990), the following set of phonological rules are provided by Universal Grammar (UG). I have added an additional rule shown in (30d):

(30) (a) spread α

(b) delink α

(c) insert α

(d) delete α



The spreading rule allows the possibility that a feature or node may be shared by two different segments through the addition of an association line between the feature or node and a segment. The delinking rule recognizes the fact that a feature can remain unrealized if an association line that links it to a segment is deleted. The insertion rule allows an association line or a new feature to be added to the representation. Finally, the deletion rule accounts for circumstances where an entire segment is deleted in production.

Rice & Avery (1995) also posit a theory of segmental acquisition based on feature geometry. According to their model, as well as the models of Bernhardt and Fee, initially the child has an impoverished or minimal structure. The inventories are built up montonically, or in a step-by-step fashion. The introduction of new feature contrasts results in segmental elaboration as more complex segments are added to the geometry (cf. Rice & Avery, 1995, p. 35). In this model, acquisition occurs along a predetermined pathway under each organizing node. For example, under the place node the first distinction learned is between coronal and peripheral.

While there is a predetermined order of acquisition within each organizing node, Rice & Avery's theory does allow for variable learning paths. For example, one child may learn the distinctions within the place node first, while another child may first learn the distinctions under the laryngeal node. Their theory also recognizes individual variability in the form of favorite sounds (referred to above as systematic sound preferences) and frequency effects. Children's favorite sounds are found in places where there is a bare place node; the children add a certain feature in all of the time, such as [labial] indicating a preference for labial sounds. These default sounds have no phonological relevance and are just the child's personal preference. The role of frequency effects is demonstrated by the different sounds found in early babbling and first words of children from varying linguistic backgrounds. For example, more coronal sounds may be heard in the babbling of an English child than a child acquiring a language that contains fewer coronal sounds.

Rice & Avery's theory is similar to the theories posited by Fee (1995) and Bernhardt (1992a). All three theories posit that children have an initial state. Fee recognizes that this is provided by UG. Rice & Avery assume that under each organizing node there is a predetermined pathway for development. This is not the case for the other theories, although all recognize that the default, or unmarked, features are acquired first and the more complex contrasts are learned through exposure to the target language. In all three theories segmental inventories are built up as a function of the acquisition and elaboration of more complex features.

In terms of development, the default segments are the segments that have minimal underlying feature specification (Bernhardt & Stoel-Gammon, 1994, p. 133). These are the segments that are acquired early in the phonological acquisition process. Thus, /h/ and /ʔ/ are the likely defaults for English, since they have little structure in the underlying representation. They are composed only of laryngeal features and therefore become defaults for segments that are composed of specified features, which have yet to be acquired. For example, children who have not developed the coronal place node will often substitute a glottal stop for /t/ and /d/. For further discussion of the acquisition of feature geometry see Brown & Matthews (1997).

2.1.4 Segmental complexity

Rice (1992, p. 64) states that the more elaborate a segment's structure is, the more complex the segment is. For example, a stop is not as complex as a fricative because the former has less branching structure under the root node than the latter; this can be seen by contrasting the representations of /p/ and /f/ in the following example:

(31) /p/
root
|
oral-cavity
|
C-place
|
[labial]

/f/
root
|
oral cavity
|
C-place [+continuant]
|
[labial]

Rice also notes that the more structure present in a segment, the more marked that segment is. According to Rice, children tend to acquire the simple segments before more complex segments.

2.1.5 The increased role of representations in nonlinear phonology

Bernhardt (1992a, p. 261) notes that when a nonlinear phonological framework is adopted, the number of rules required to analyze a child's phonological system is reduced. Working within a nonlinear framework, it is assumed that a child's phonological system has an underlying phonological representation. As noted earlier, Bernhardt & Stoel-Gammon (1994) assume that that this representation acts as a filter. Bernhardt & Stoel-Gammon suggest that information that diverges from the child's representation is ignored and does not pass through the filter. For example, a child's speech may include the following set of errors:

(32) toe [po] (labialization)
dog [gag] (velarization)
duck [bʌk] (labialization or fronting)

An analytical framework that emphasizes phonological rules would assume that these errors result from the processes of labialization, velarization, and fronting respectively. By contrast, in a nonlinear framework, all of the above errors can be explained by assuming that the child has not yet developed a coronal node in her/his geometry and as a result, the bare coronal node is filled in by other features for which s/he has a systematic sound preference. This is demonstrated in (33):

(33) /t, d/ insert [labial]: [p, b]

C-Place C-Place
|
[labial]

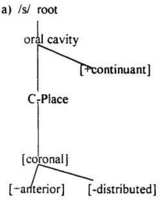
In the case of 'dog' the [dorsal] feature of /g/ spreads to the bare place node of /d/, an example of velarization and consonant harmony. This is shown in (34):

(34) /d/ /g/

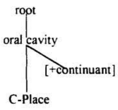
C-Place C-Place
|
[dorsal]

This child would also have difficulty pronouncing a complex coronal segment such as /s/ which has the structure shown in (35a). Since the child cannot produce the feature [coronal], s/he may produce a segment such as [h] as shown in (35b) as a default; [h] is a simpler segment in that it has no place features and therefore only requires a bare place node:

(35)(a) /s/



(b) [h]



2.2 Prosodic Theory

Children come to the language learning process equipped with an innate prosodic structure, which is a CV syllable shape (Bernhardt, 1992a, p. 226). Children may also have a bimoraic minimal word, namely CVV (Bernhardt & Gilbert, 1992, p. 126). As children are exposed to the input from the language they are learning, they gradually build up all of the language specific syllable and word shapes, such as CVC, CVCV and CCCV.

UG provides a set of rules for building prosodic structure (Fee, 1995). A set of rules for building the core syllable (σ_c) of the language as well as a set of rules for building the minimal word (wd_{min}) are provided by UG (cf. Fee, 1995, pp. 52-3). At the earliest stages of phonological acquisition the child can only produce a monomoraic core syllable (CV). A mora is a unit of syllable weight. However, only the moraic segments, namely vowels and rhyme consonants, are obligatory. As acquisition progresses, language specific rules which allow complex onsets, coda consonants, and complex vowels are learned by the child.

Normally, the minimal word contains one bimoraic foot consisting of at least two morae (Wd_{min}=F=[μμ]) (McCarthy& Prince, 1995, p. 321). Because the minimal word contains two morae, the child initially builds this word with two monomoraic syllables of the type shown in Figure 7(a). Before the child can build the minimal word with bimoraic syllables, s/he must acquire the language specific rules that allow syllables to contain more than one mora. As acquisition proceeds, therefore, children will learn to produce words that contain long vowels (7b), diphthongs, and coda consonants (7c). Children of all linguistic backgrounds learn to produce words containing more than three syllables relatively late in the language acquisition process since such syllables are more productively complex.

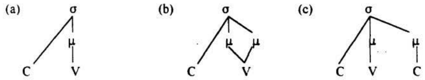


Figure 7. Developing syllable structure for children's minimal words.

The theories posited by Bernhardt (1992a) and Fee (1995) are similar in that they both assume that children are equipped with a limited amount of prosodic structure at the initial state of phonological acquisition, that being a CV syllable template. As children are exposed to input from the target language they gradually build up all of the language-specific prosodic structure. For further discussion of the acquisition of prosodic structure see Kehoe & Stoel-Gammon (1997).

2.3 Tier Interaction

Although nonlinear phonology presupposes autonomous tiers (prosodic vs. segmental), some interaction does occur between tiers (Bernhardt & Stoel-Gammon, 1994, p. 133). Even if a child has acquired the segmental inventory of his or her language, speech production may not reflect this because of the child's prosodic constraints. Thus, segments can only be realized in the syllable positions that have been acquired. For example, a child may have acquired the segments /ŋ/ and /ʒ/. At the same time, s/he may not have acquired a syllable template inventory that includes coda consonants. Therefore, since /ŋ, ʒ/ only occur in coda positions in English, they would not be heard in the child's speech production.

2.4 Conclusion

In this chapter the developmental implications of nonlinear phonology have been discussed. Working within a nonlinear phonological framework, it is assumed that children have an innate, incomplete phonological representation in place at the beginning of phonological acquisition. This representation is based on the unmarked or default features and prosodic templates that are provided by UG. As children are exposed to input from the language they are acquiring, language specific, marked aspects are added to their inventories. Hierarchical representations suggest that information can be acquired from the segmental and prosodic tiers independently, and there is also some tier interaction during phonological acquisition.

In this study the nonlinear framework will be used to analyze the phonological systems of two children with deviant phonological development.

3.0 Methodology

3.1 Subjects

Data for this study was obtained from two previous studies (Grunwell & Yavas, 1988 and Miccio & Elbert, 1996) which focused on the speech patterns and intervention of phonologically disordered children.

The first subject for the study (Grunwell & Yavas, 1988) was a 9;0 year-old monolingual English speaking male (Graham). Graham's difficulties included pronunciation problems, characteristics commonly associated with a general language impairment, and major problems in all areas of school curriculum. He did, however, have normal hearing for speech and was well adjusted socially.

The second participant for the study (Miccio & Elbert, 1996) was a 3;4 year-old female English speaking female (Stacy). This child was referred to a speech-language pathologist for a phonological assessment following a large- scale preschool developmental screening process. The developmental screening indicated normal attainment of sensorimotor milestones such as sitting, crawling, and walking.
She showed no signs of health problems and had no documented history of hearing problems. According to her mother, she began producing recognizable words at around ten months of age and sentence production began at around two years of age. Her mother first noticed her speech delay somewhere between the age of two and three years old. Her sister (age 5;6) was also diagnosed as phonologically disordered while her brother (age 2;0) had no identifiable speech delays. Stacy was aware of her unintelligibility and became frustrated when others had difficulty understanding her speech.

3.2 Assessment

Graham was assessed using the PACS: Language Elicitation Materials (Grunwell, 1991). This test contains 200 picture cards that illustrate 200 words. The elicitation of these words provides a sample of segments in the syllable and word positions where they occur in target language. The child was shown each picture in a naming task and in addition to providing the name of the picture was asked for a brief description of the picture. The data gathered by Grunwell & Yavas (1988) contains only one modeled response *dinosaur* whereby the individual implementing the test pronounced the word and Graham repeated it. For further details of data collection see Grunwell & Yavas (1988).

Several standardized tests were used to assess Stacy's general language and phonological abilities, such as the Oral Speech Mechanism Screening Examination Revised (St. Louis & Ruscello, 1986), the American National Standards Institute (ANSI) Hearing exam (American National Standards Institute, 1969), the Peabody Picture Vocabulary Test-Revised (PPVT-R) (Dunn & Dunn, 1981), and the Test of Early Language Development (TELD) (Hresko, Reid, & Hammill, 1981). Results of these tests indicated normal hearing for speech and showed no general language delays. Stacy exhibited good comprehension abilities and had no difficulty following directions during testing. Due to the unintelligibility of her speech, she was not given a standardized test to assess narrative language skills. It was also noted that her participation in conversation was minimal during testing. Two measures were used for phonological assessment. On the Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 1986) she made 57 errors, placing her in the >1 percentile for her age group. To obtain a more comprehensive measure of her phonological abilities, a 104-item subset of a probe developed by Gierut (1985) was administered. In this measure, children are given the opportunity, through a picture-naming task to pronounce all of the English consonants in the position in which they occur (prevocalically, intervocalically and postvocalically) in single words. Data from this measure was reanalyzed in the present study using nonlinear phonology.

4.0 Analysis and Discussion

In this chapter the phonological systems of Graham and Stacy are analyzed. For each data sample, the analysis is divided into three sections: segmental analysis, prosodic analysis, and tier interaction.

4.1 Analysis of Graham's Phonology

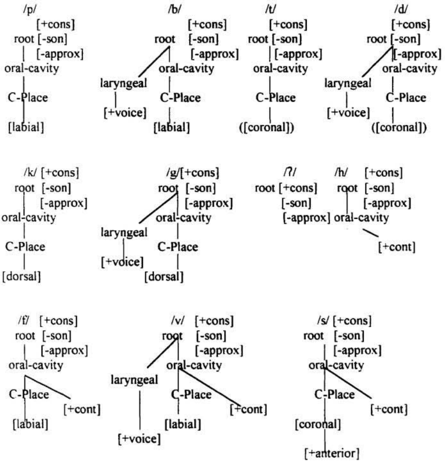
4.1.1 Segmental analysis

Based on the data from Grunwell & Yavas (1988), Graham's phonetic inventory is represented in Table 2.

Table 2. Graham's Phonetic Inventory.

	Labial	Labio-dental	Inter-dental	Alveolar	Alveo-Palatal	Velar	Glottal
Stop							
Voiceless	p			t		k	ʔ
Voiced	b			d		g	
Fricative							
Voiceless		f		s, ɬ	ʃ		h
Voiced		v					
Affricate							
Voiceless					ʧ		
Voiced							
Nasal	m			n			
Liquid				l			
Approxi-mant	w						

Through analysis of the segmental inventory in Table 2, it was determined that Graham's feature geometry for each of the segments in his inventory is as follows:


/p/
[+cons]
root [-son]
[-approx]
oral-cavity
C-Place
[labial]
/b/
[+cons]
root [-son]
[-approx]
laryngeal
oral-cavity
[+voice]
C-Place
[labial]
/t/
[+cons]
root [-son]
[-approx]
oral-cavity
C-Place
([coronal])
/d/
[+cons]
root [-son]
[-approx]
laryngeal
oral-cavity
[+voice]
C-Place
([coronal])
/k/ [+cons]
root [-son]
[-approx]
oral-cavity
C-Place
[dorsal]
/g/[+cons]
root [-son]
[-approx]
laryngeal
oral-cavity
C-Place
[+voice]
[dorsal]
/ʔ/
root [+cons]
[-son]
[-approx]
/h/ [+cons]
root [-son]
[-approx]
oral-cavity
[+cont]
/f/ [+cons]
root [-son]
[-approx]
oral-cavity
C-Place
[+cont]
[labial]
/v/ [+cons]
root [-son]
[-approx]
oral-cavity
laryngeal
C-Place
[+cont]
[labial]
[+voice]
/s/ [+cons]
root [-son]
[-approx]
oral-cavity
C-Place
[+cont]
[coronal]
[+anterior]

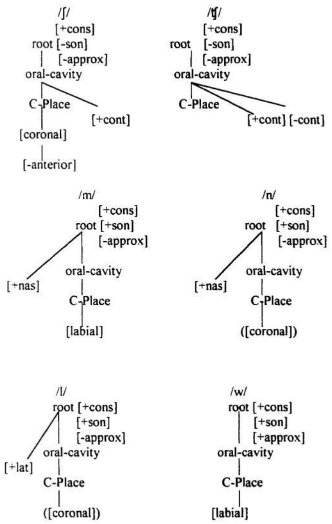
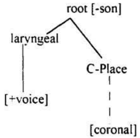


Figure 8. Graham's feature geometry for acquired segments.

Figure 8 represents the features which Graham had acquired at the time of testing. The minimum number of features have been included in these trees to capture Graham's segmental inventory. For example, Graham has acquired the features necessary to contrast /s/ and /ʃ/, but does not have the contrast between /s/ and /θ/. Therefore, the feature [±anterior] has been included in the trees in Figure 8, but the feature [±distributed] does not appear in the representation of the acquired fricatives. Thus, the child's representations are impoverished as compared to the adult representation. The segment [ɬ] has been omitted from this figure and is discussed on page 54. A comparison of Figure 1, a fully developed adult feature geometry, and Figure 8 indicates that Graham's inventory was not fully developed. The [±distributed] contrast was not found in Graham's inventory. In addition, /ʧ/ is not specified for place as it is the only affricate in Graham's inventory and therefore has no others to contrast with. As can be seen in the representations, all nodes of the feature geometry of English were in place. The feature [+ approximate] was not fully developed as the approximate /j/ was not found in Graham's inventory. (However, it should be noted that this conclusion is somewhat tenuous as /j/ was only targeted in one instance in which case it was deleted). The feature [+voice], while fairly well developed for stops, was also not fully acquired by Graham at the time of testing. This conclusion is based on the fact that with the exception of /v/, no other voiced fricatives or affricates were present in the segmental inventory while the voiceless fricatives and affricates of the same place of articulation had been acquired. Also, the voiced velar stop /g/ was not produced with the same consistency as the other stops. The feature [+nasal] had been fully developed although the velar nasal /ŋ / is absent. The absence of the velar nasal is due to Graham's syllable structure constraint against coda consonants, the only position in which this segment appears in English. This will be discussed further under the analysis of tier interaction.

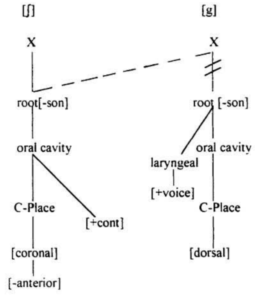
An analysis of the phonetic inventory and the feature geometry reveal that Graham had fully acquired the labial and coronal stops /p,b,t,d/ and the voiceless velar stop /k/. Graham made several errors, however, when the voiced velar stop /g/ was targeted; for example, /g/ was produced as a [d] in the target word given in (36):

(36) 'girl' [dɛ]



In this word, the dorsal place features were not realized. That is, there is a bare place node. To fill in structure under the C-Place node, Graham inserted a default coronal feature. In another example, /g/ was phonetically realized as [ʃ] in the word 'sugar' [ʃuʃə] as illustrated in the following example:

(37)

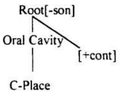


In this example, all features of the first consonant /ʃ/ were spread to the consonant /g/ thereby causing it to be realized as [ʃ]. All features of /g/ were then delinked.

The feature [+continuant] was found in Graham's feature geometry. However, with the exception of /v/, the only fricatives and affricates in the inventory were voiceless. The voiceless [+continuant] segments of all places of articulation were present with the exception of the voiceless interdental fricative /θ/. This fricative, as well as its voiced counterpart /ð / were missing from Graham's inventory: from this we can conclude that Graham did not have the feature [±distributed] in his feature inventory. The lack of voiced fricatives and affricates in the segmental inventory was the result of the feature [+voice] not being fully acquired in combination with the feature [+continuant] not being completely developed in Graham's inventory. The result is that the segments

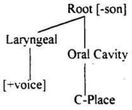
/z,ð,ʒ,dʒ/ were not found in Graham's segmental inventory. Graham compensated for the absence of these segments in several ways. In one word containing the segment /z/, he replaced it with [s]. In this case, all features of the substituted segment matched with the exception of the underdeveloped voicing features as in (38):

(38) 'zebra' [səʔ]



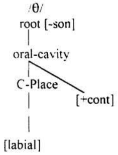
/ð/ also was not found in Graham's segmental inventory nor was its voiceless counterpart /θ/. As mentioned above, these fricatives are absent due to the fact that Graham did not have the coronal feature [±distributed] at the time of testing. The voiced interdental fricative /ð/ was found to be realized as [d] as in the following example:

(39) 'that' [daʔ]



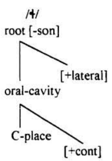
In this example, the features [+continuant] and [-distributed] were not realized and as a result the segment was realized as voiced coronal stop ([d]). Meanwhile, the voiceless interdental fricative /θ/ was realized as [f], a labial fricative, in the target word 'thumb' [fʌ]. This represents a case of labialization whereby Graham inserted the [labial] feature under the C-Place node, thereby producing a labial fricative rather than the targeted [cor, -distr] fricative, as shown in the next example. This example illustrates a systematic sound preference for [labial] sounds:

(40)



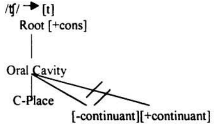
The voiceless alveopalatal fricative /ʃ/ was realized correctly in most instances where it was targeted except for when prosodic constraints prevailed (discussed in more detail below). The one exception was found in the target word 'shaving' which was produced as [ɬaʔ]. Here, /ʃ/ was replaced by a lateral fricative which shares the C-place features and the feature [+continuant] with the segment in question. Furthermore, this segment, whose representation is shown in the next example, is not part of the English consonantal inventory. As noted in an earlier chapter it is common for phonologically disordered children to produce segments which are not part of the language being acquired.

(41)



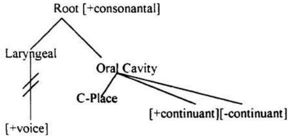
In addition, the voiced alveopalatal fricative /ʒ/ was not present in Graham's inventory at the time of testing. This is due, in part, to the fact that in English this segment occurs exclusively in syllable coda position, a position which was very underdeveloped by Graham at the time of testing. The voiceless alveopalatal affricate /ʧ/ was found in Graham's inventory. One example where it was not realized correctly is in the target word 'church' [təʔ]. In this example, the [+continuant] portion of the affricate was not realized resulting in a stop. This "process" is traditionally known as deaffrication:

(42)



The voiced alveopalatal affricate /ʤ/ was also missing from Graham's phonetic inventory. In some instances it was realized as [d], as in the target word 'jam' [da]. This is due to the non-realization of the [+continuant] part of the affricate. This is another example of deaffrication, equivalent to the above example where /tʃ/ is realized as [t]. Conversely, in the target word 'hedgehog', /dʒ/ was produced as [tʃ], yielding the word [ətʃɒʔ]. This resulted from Graham choosing the unmarked voiceless laryngeal feature rather than the feature [+voice] as shown in the next example. Since Graham produced an affricate in this case it may be assumed that he is in the process of acquiring affricates.

(43) /dʒ/ → [tʃ]



The fricative /h/ was present in Graham's phonetic inventory. When targeted, if it was not produced correctly it was deleted, as demonstrated in the pronunciation of the example word 'hedgehog' discussed above.

The feature [+approximant] had been partially established. The segment /w/ was acquired at the time of testing while the segment /j/ was not. However, this segment was only targeted in one word *Indian* and in this instance /j/ was deleted. This was not a good target word since [ɪndjən] or [ɪndʒən] is the common pronunciation. Therefore, the data sample is not conclusive as to whether or not /j/ had been acquired at the time of testing.

Only one of two liquids were present in Graham's inventory at the time of testing. The feature [+lateral] had been acquired, as was evident from the correct realization of target words in which the segment /l/ occurred; for example 'lamp' which was produced as [la]. In addition the lateral fricative /ɬ/, although not part of the English consonant inventory, was also found in the data sample, for example, in Graham's production of the target word 'sledge' as [ɬɛʔ]. This is an example of blending or coalesence, which is discussed below in (60). The liquid segment /r/, on the other hand, was not found in Graham's inventory. When targeted, it was produced as [w] indicating that the [+consonantal] feature was not in place for this segment, thereby yielding an approximant substitution.

The glottal stop /ʔ/ was commonly found in Graham's speech sample as a substition for other consonants which had not been acquired. This process is referred to as glottal substitution. As noted in an earlier chapter, this segment is a common sound preference in the speech of children with delayed phonological development due to its ease of production presumably resulting from its lack of structure; the only feature contained in this segment is [+consonantal]. This structure is shown below along with several examples from Graham's speech sample where he produces this segment:

(44) /ʔ/

Root [+consonantal]

'lipstick' [ləʔə]
'milk' [mɪʔ]
'skipping' [kɪʔ]

In summary, all feature geometry nodes were present in Graham's inventory at the time of testing. The features which were not well established were the Root node feature [+approximate], the Laryngeal node feature [+voice] for non-stops, the coronal contrast [±distributed], and the [±lateral] contrast for /l/ and /r/.

Several of Graham's errors could be predicted by feature geometry theory. For example, in (38), the feature [+voice] has been replaced by [-voice], a lesser marked form, and therefore more commonly found in children's inventories.

4.1.2 Prosodic analysis

Graham's syllable and word shape inventory appeared to lag behind his segmental development. In fact many of the segmental errors he made were the result of segments which were acquired being targeted in prosodic environments which he had yet to develop.

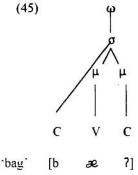
In Graham's production of the 170 target words that were used during testing, 118 (69.4%) of his productions matched the target word in terms of the number of syllables per word. Of the 118 words that matched the target word for the number of syllables 97 (82.2 %) were monosyllabic words, 19 (16.1%) were disyllabic words, and 2 (1.7%) were trisyllabic words.

4.1.2.1 Syllable and word template inventory

In the speech sample test, there were 252 syllables targeted. Of these 252 syllables, only 61 (24.2%) of Graham's syllables matched the syllable template that was targeted. Of the syllables which were of the correct shape 34 (55.6%) were CVC syllables, 21 (34.4%) were CV shaped syllables, 4 (6.6%) were VC syllables, and 2 (3.3%) were comprised of a simple vowel. This indicates that, of the templates targeted, the CVC template was the best developed in Graham's syllable repertoire at the time of testing. Of the 170 words used during testing, Graham's productions only matched the target word templates in 27 (15 %) of the words. Of the matching word templates, 24 (88.9%) were monosyllabic, 2 (7.4%) were disyllabic, and 1 (3.7%) was trisyllabic. The word templates he produced correctly were of 5 shapes. The most common was CVC which comprised 20 (74.1%) of the correctly matched templates. The templates CV, VC, and CV.CV each accounted for 2 (7.4%) of the matching word templates, while the trisyllabic form CV.CV.CVC was only produced once; it made up 3% of the correctly matched word templates.

In total, Graham produced 197 syllables. There were 5 syllable templates and 13 word templates found in Graham's inventory. The first, and most prevalent, syllable and word template was CVC, which was found to be produced 115 times; it comprised 58.4% of Graham's syllable inventory and was produced 101 times (59.5%) as a word template. This syllable/word shape is composed of two moraic segments; it is bimoraic. This is illustrated below with an example word from Graham's speech. In the representations included in this section, the foot level has been omitted because it is unclear how to analyze foot structure, given that the transcriptions from the previous studies did not include stress.

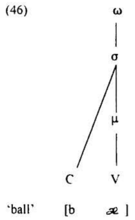
(45)



This template meets the requirements for the prosodic word minimum as it is bimoraic (McCarthy & Prince, 1995, p.p.321). This explains why this template is so common in Graham's inventory: he is favoring the syllable template which best meets the prosodic word minimum.

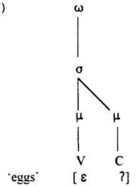
The second most common syllable template found was CV which was produced 71 times, or made 36% of the syllables produced. It was also a common word template in his inventory as it comprised 37 (21.8%) of the word shapes produced. This template is is shown below in (46):

(46)



The bimoraic syllable shape VC, shown in the next example, was produced 6 times, or made up only 3% of the syllable inventory of Graham's data sample while it accounted for 5 (2.9%) of the word templates produced during testing.

(47)



The template CV was more common than VC because VC violates the constraint against syllables without an onset; that is; syllables with onsets are more favored or less marked than syllables without onsets. The VC template meets the bimoraic word minimum.

The monomaraic syllable consisting of a simple vowel (V) made up 2% of the syllables, or was produced 4 times during testing. Only one word (0.6%) was made up of a single vowel. In the example word in (48), only the first syllable of the word produced is provided to demonstrate a syllable made up of a simple vowel. (The second syllable of the was produced but has been omitted for the purposes of this example):

(48)

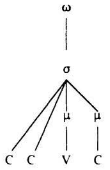
$$\begin{array}{c} \sigma \\ | \\ \mu \\ | \\ \mathrm{V} \end{array}$$

'hedgehog' [ə]

4.1.2.1.1 Consonant clusters

Graham had only one syllable shape in his inventory with a complex onset. This template was of the form CCVC. This template is bimoraic and made up only 0.51% of the syllable inventory in Graham's speech sample; it was produced only once. Similarly, it was produced as a word template only once, and represented 0.6% of the words he produced.

(49)



'present' [p w ε ʔ]

The lack of consonant clusters can be explained by a prosodic constraint against complex onsets which are more marked than simple onsets (Blevins, 1995, p. 218).

Graham also showed a preference for less marked obstruent onsets over more marked, more sonorous onsets. This preference can be explained by the Sonority Sequencing Principle (SSP) (Clements, 1990) in that the first demisyllable has a steeper rise in sonority if the onset is an obstruent than if the onset is a sonorant. The SSP is discussed in more detail below. When clusters of the shape *stop + liquid* were targeted, the cluster was realized as the stop. This is illustrated in the following example words from the data sample:

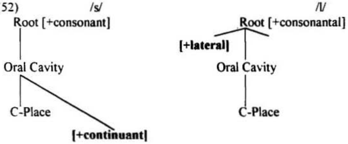
(50)	/pl/	'plate'	[paʔ]
	/pr/	'pram'	[pa]
	/bl/	'blue'	[bu]
	/br/	'brick'	[bɪʔ]
	/tr/	'tree'	[tε]
	/dr/	'dress'	[dεʔ]
	/kl/	'clouds'	[kɑʔ]

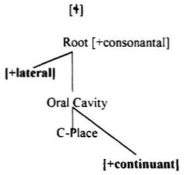
/kr/ 'crash' [kaʔ]
/gl/ 'glass' [gɑʔ]
/gr/ 'grass' [gɑʔ]

When the cluster targeted consisted of *a fricative - liquid* sequence, the resulting production was the less sonorous fricative. This is illustrated by the following examples from Graham's speech sample:

(51) /fl/ 'flag' [faʔ]
/fr/ 'fridge' [fɪʔ]
/sl/ 'sleeping' [si]; 'sledge [ɬɛʔ]
/θr/ 'three' [fi]

As can be seen from the examples given above, the fricative produced was not always the target fricative. For example, in the word 'three', [f] is produced. This is due to the fact that Graham did not have the interdental voiceless fricative in his repertoire and [f] was always produced as a substitute. In the word 'sledge', the lateral fricative was produced for the target cluster /sl/. This is an example of 'coalescence', 'fusion' or 'blending'. The resulting segment had the [+continuant] features of the fricative and the [+lateral] features of the liquid, as shown below in the following diagram:

(52)




When the cluster targeted was a *fricative* - *stop* cluster, such as the ones in (53), the stop was retained in Graham's pronunciation. Graham appeared to prefer stops, as is evident from the examples of stopping in the following examples:

(53) /st/ 'star' [tɑr]
/sp/ 'spade' [peʔ]
/sk/ 'school' [kuʔ]

When the target word contained a *fricative* - *nasal* cluster the form produced varied. As can be seen in the next example, when the nasal in the cluster was /m/, the word began with [m]. However, when the cluster was a fricative + /n/, the results differed. In one instance [n] was produced while in another target word it was the fricative /s/ that remained. The following data set illustrates the results of targeting a fricative + nasal cluster:

(54) /sm/ 'smooth' [muʔ]
/sn/ 'snail' [naɪ]; 'snake' [saʔ]

Finally, when word initial clusters of the sequence *fricative - stop - liquid*, or *fricative - stop - approximate* were targeted, Graham's word began with the least sonorous segment, a word initial stop, for example:

(55) /spl/ 'splash' [paʔ]
/spr/ 'spring' [pɪʔ]
/str/ 'string' [tɪ]
/skw/ 'square' [kɛ]

Thus, we see that, when presented with a target word containing a consonant cluster, Graham produced the word with a singleton onset, and the onset consonant was the least sonorous constituent of the cluster, with the exception of *fricative - nasal* clusters.

The above patterns of consonant cluster realization can be explained by the Sonority Sequencing Principle (SSP) (Clements, 1990, p.285). The SSP assumes the sonority hierarchy (Clements, 1990, p. 292) in (56):

(56) obstruents < nasals < liquids < glides

The SSP states that sonority rises steeply towards the nucleus and falls gradually after the nucleus. Therefore, Graham is using the least marked onset when reducing his consonant clusters to obstruents.

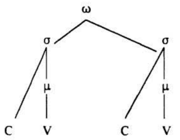
While several words with final clusters were presented to Graham, none were produced due to Graham's prosodic constraints on the production of word or syllable final consonants. That is, Graham's syllable inventory did not include templates with codas. This is discussed in a section to follow. However, in one instance, the final cluster /rf/ was targeted and Graham produced a word ending in [f]. This is demonstrated in the following example:

(57) 'scarf' [kaf]

4.1.2.1.2 Disyllabic words

There were seven disyllabic words in Graham's inventory. The most common disyllabic template was CV,CV. Graham's preference for this template can be explained by the fact that it meets the bimoraic word minimum and is therefore an unmarked prosodic word. Nine (5.3%) of the words Graham produced were of this form. This word template is illustrated in the next example. However, this target word is a compound so it is possible that Graham considered this form to be two morphological words.

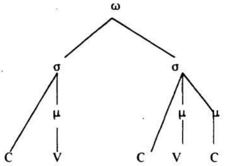
(58)



'rainbow' [w ʌ b ə]

The next most common common disyllabic word template found in Graham's speech sample was CV.CVC which made up 3.5%, or 6, of the words he produced. This is shown in the next example:

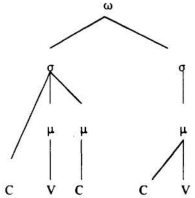
(59)



'motorbike' [m ə b ʌ ʔ]

The template CVC. CV made up 3 (1.8%) of Graham's words. This template is demonstrated in (60):

(60)

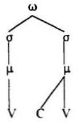


'pyjamas' [p ə ʔ d ə]

The templates shown in the two previous examples are trimoraic words. These do not occur frequently in Graham's speech because he has not developed the more complex word templates which contain more structure than the minimum prosodic word.

Graham produced 2 words with a V,CV template (1.2% of the words produced were of this form). This form has an unmarked prosodic word template but a marked syllable template since the first syllable has no onset. The structure of this word template is as follows:

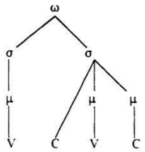
(61)



'aeroplane' [a p ə]

The templates, [V,CVC], [CVC,CVC], and [VC,CV] were each produced only once; each comprised 0.6% of the words produced. They are illustrated in the next three examples:

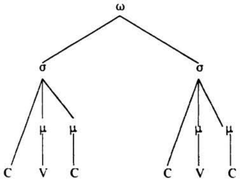
(62)



'hedgehog' [ə ʧ ɒ ʔ]

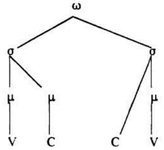
The example in (63) is also a compound and may also be considered as two prosodic words:

(63)



'toothbrush' [t u ʔ b ʌ ʔ]

(64)

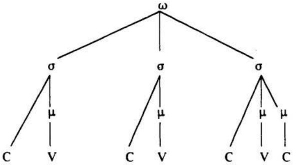


'under' [ʌ n d ə]

4.1.2.1.3 Trisyllabic words

Graham produced only 2 trisyllabic words (only 1.2% of the words produced were trisyllabic) both of the shape CV,CV,CVC. This template is illustrated below:

(65)

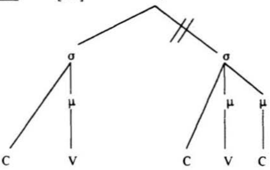


'roundabout' [w ʌ d ʌ b ʌ ʔ]

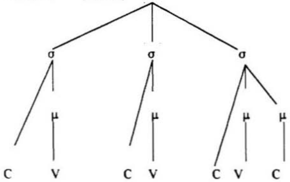
4.1.2.2 Syllable deletion

As already discussed, the majority of words Graham produced were monosyllabic. In the majority of instances, when multisyllabic words were targeted, the syllable corresponding to the weak, or unstressed, syllable in adult English was deleted. Of the 64 disyllabic words targeted, 46 (71.9%) were produced as monosyllables. There were 9 trisyllabic words of which only 2 (22.2%) were produced as trisyllabic. Five of the words, or 55.6% were produced as disyllabic words while 2 (22.2%) were produced monosyllabically. Graham typically deletes the weakest syllable of the target word. This process is illustrated in the next set of examples where the underlined portion of the word is the weak syllable that was deleted. The diagrams in this example represent the adult word templates. In the case of 'bucket' the weak syllable is the second syllable and this syllable was deleted by Graham due to the fact that the target word was trimoraic and he had not fully mastered this complex word type at the time of testing. In his production, he added a coda consonant to the end of the first syllable, perhaps indicating that he was aware that another syllable followed but unable to produce it. In the case of 'motorbike' the second syllable, which is the rightmost syllable of the first foot and therefore the weak syllable, was deleted:

(66a) 'bucket' [bʌʔ]



(b) 'motorbike' [məbʌʔ]



In summary, Graham's prosodic tier was underdeveloped at the time of testing. His productions tended towards the universally unmarked syllable and word templates. For example, his most common production was CVC. This is a bimoraic form and therefore meets the requirements for the minimal prosodic word and is a relatively unmarked syllable template. He produced forms of the shape CV more frequently than VC because the latter form does not have an onset consonant and is therefore a marked syllable template. His disyllabic productions were mainly bimoraic, such as CV,CV in which each syllable had an onset consonant. More complex word forms, such as trimoraic words, were not found frequently in Graham's inventory. He was not able to produce complex onsets and had a limited number of syllable- and word- coda consonants. The interaction of bimoraic word and syllable templates favored CVC and CV syllables.

4.1.3 Tier interaction

Analysis of Graham's speech sample indicates that different segments and features were acquired in different prosodic positions. Graham's inventory was best developed in word initial (WI) position. The following Table represents the segments that appear in word initial position in Graham's speech sample.

Table 3. Graham's WI Phonetic Inventory.

	Labial	Labio-dental	Inter-Dental	Alveolar	Alveo-Palatal	Velar	Glottal
Stop Voiceless Voiced	 p b			 t d		 k g	 ʔ
Fricative Voiceless Voiced		 f v		 s, ɬ	 ʃ		 h
Affricate Voiceless Voiced					 ʧ		
Nasal	m			n			
Liquid				l			
Approxi-Mate	w						

Table 3 illustrates that Graham's word initial phonetic inventory matched his overall segmental inventory seen in Table 2. Graham's contrastive feature geometry for word initial position is shown in the next Figure:

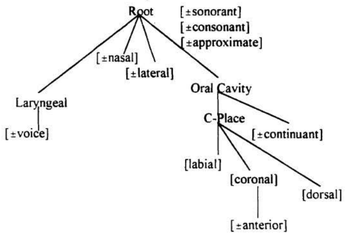


Figure 9. Graham's WI feature geometry.

Close examination of Graham's WI feature geometry reveals that it is equivalent to Graham's overall feature geometry given in Figure 8 which indicates that this position is very well developed.

The following Table represents Graham's phonetic inventory in Syllable initial within word position (SIWW):

Table 4. Graham's SIWW Phonetic Inventory.

	Labial	Labio-dental	Inter-Dental	Alveolar	Alveo-Palatal	Velar	Glottal
Stop Voiceless Voiced	 p b			 t d			
Fricative Voiceless Voiced		 v		 s			
Affricate Voiceless Voiced							
Nasal	m						
Liquid							
Approxi-Mate							

As can be seen in Table 4, this prosodic position was not as well developed as word initial position. Furthermore, while several segments occurred in this position, none of them were produced correctly every time they were targeted. The following diagram represents the contrastive features which have been partly established in SIWW position:

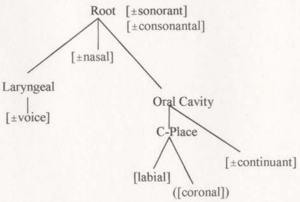


Figure 10. Graham's SIWW feature geometry.

The features [±lateral], [dorsal], and [±approximant] were completely absent in this position, as were the coronal place features [±anterior] and [±distributed]. There was only one segment containing the feature [+nasal].

In syllable final within word position (SFWW), the only targeted segment which was realized correctly was /n/. The segment /ʔ/ occurred frequently as a substitute for segments which were not yet acquired. Table 5 illustrates the segments acquired in SFWW position:

Table 5. SFWW Segmental Inventory.

	Labial	Labio-dental	Inter-Dental	Alveolar	Alveo-Palatal	Velar	Glottal
Stop Voiceless Voiced							ʔ
Fricative Voiceless Voiced							
Affricate Voiceless Voiced							
Nasal				n			
Liquid							
Approxi-mate							

Figure 11 below shows Graham's syllable final within word (SFWW) contrastive feature geometry:

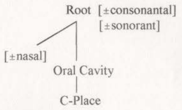


Figure 11. Graham's SFWW feature geometry.

In word final position, the same segments as in SFWW position were established. In addition, in one instance /f/ also occurred as a substitute for another segment. The following Table demonstrates Graham's word final (WF) segmental inventory:

Table 6. WF Segmental Inventory.

	Labial	Labio-dental	Inter-Dental	Alveolar	Alveo-Palatal	Velar	Glottal
Stop Voiceless Voiced							ʔ
Fricative Voiceless Voiced		f					
Affricate Voiceless Voiced							
Nasal				n			
Liquid							
Approxi-Mate							

Figure 12 represents Graham's feature geometry in word final position. Since /f/ was only produced in WF position once, the features of which it is composed are not represented in the contrastive geometry in Figure 12.

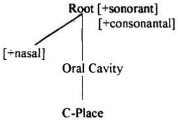


Figure 12. Graham's WF feature geometry.

With the exception of one case of /f/ and a small number of cases of /n/, the only segment that Graham consistently produced word finally was /ʔ/; this clearly indicates that he could not produce most features in this environment. /ʔ/ has a minimal feature structure with no place features and only the root node feature [+consonantal]. Therefore, although Graham was aware of the presence of a consonantal slot in coda position, he could only produce a limited number of features in this position. The fact that /n/ and /f/ were present in some words in the data in coda position indicates that the acquisition of word and syllable final consonants was in progress but still very rudimentary at the time of testing. Other evidence was also present in Graham's speech sample to indicate that he perceived that there is a coda position in the target syllables even if they were not always produced. Consider his production of the following target word:

(67) 'pram' [pã̆]

The nasalization of the vowel may be considered anticipatory assimilation of the nasal consonant in coda position, which indicates that he perceived the final consonant but was unable to produce it. This is not surprising since children's competence is commonly more mature than their language performance at early stages of acquisition.

In summary, the word position that was best developed was WI where all segments that had been acquired were produced. Having a fuller inventory in WI position is a trend common in early language acquisition. There were several segments and features produced in SIWW position, while SFWW and WF positions contained virtually no phonetic realizations, as these environments were at an early stage of development at the time of testing. The prosodic development that had taken place seemed to be largely constrained by markedness considerations.

4.2 Analysis of Stacy's phonology

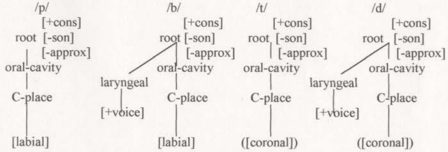
4.2.1 Segmental analysis

Based on the data provided by Miccio & Elbert (1996), the following Table summarizes Stacy's phonetic inventory across word positions; the Table summarizes her overall phonetic inventory without taking into account which segments had been acquired in various syllable and word positions.

Table 7. Stacy's Phonetic Inventory

	Labial	Labio-dental	Inter-Dental	Alveolar	Alveo-Palatal	Velar	Glottal
Stop Voiceless Voiced	 p b			 t d			 ʔ
Fricative Voiceless Voiced							 h
Affricate Voiceless Voiced							
Nasal	m			n			
Liquid							
Approxi-Mate	w				j		

As indicated by Table 7, Stacy's segmental inventory was limited when compared to a fully developed adult English phonetic inventory. Her inventory was found to be limited to stops and nasals with the exception of one fricative (/h/) and two approximants (/w, j/). Figure 13 represents Stacy's underlying feature geometry for each of the acquired segments.



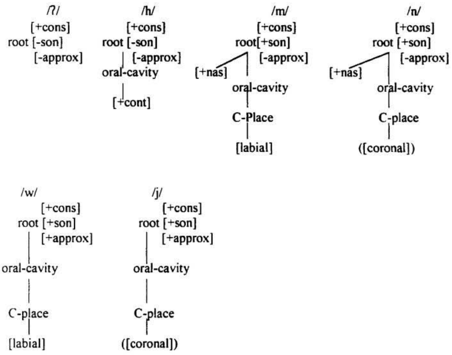


Figure 13. Stacy's feature geometry for acquired segments

As can be seen from this diagram, Stacy's feature geometry was limited at the time of testing. The feature [±lateral] was missing, the C-Place node was restricted to the features [labial] and [coronal]. The coronal features [±anterior] and [±distributed] were also missing from her feature inventory. The C-Place feature [dorsal] was absent from Stacy's geometry. The only [+continuant] segment found in her inventory was the fricative /h/. There were no other fricatives or affricates present in her speech sample. The absence of fricatives and affricates is due to an avoidance of segmental complexity. Complex segments, such as fricatives and affricates, tend to be acquired later than less complex segments.

The velar stops /k, g/ were not present in her speech sample since the feature [dorsal] had not been acquired. This cannot be attributed to segmental complexity as the feature [dorsal] is no more complex than the other place features [labial] and [coronal]. As mentioned in a previous section, children have different learning paths; it appears that Stacy is developing the [labial] and [coronal] nodes first before her [dorsal] node. This is shown by her production of the target /k/ in (69), which is a case of 'fronting':

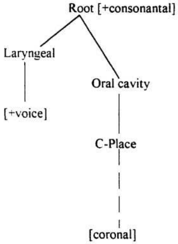
(68) 'sock' [dat]

Since she has no [dorsal] feature, her representation would have no features under the place node. To compensate for this she added a default coronal place feature as shown in the following example:

(69) Root[+consonantal]
|
Oral Cavity
|
C-Place
|
[coronal]

Similarly, for /g/ she also chose a coronal default as shown in the next example:

(70) 'gum' [dʌm]



From these examples it can be inferred that when compensating for the absence of the feature [dorsal], Stacy inserted [coronal] as a place feature default. Therefore, [coronal] appeared to be a systematic sound preference at the time of testing.

Stacy's segmental inventory contained no fricatives (with the exception of /h/) or affricates. This is due to the fact that the feature [+continuant] was not developed, as demonstrated in (68) above and in (71):

(71) 'laugh' [lap]

/f/ → [p]

Root [+cons]

Oral Cavity

C-Place

[labial]

Since Stacy had no [+continuant] feature the target sound /f/ was produced as a labial stop [p] which differs from /f/ only in the feature [+continuant]. Similarly, Stacy did not produce a /v/, as shown in the following example where the [+continuant] feature was again absent from the representation, resulting in a stop. This process is traditionally known as 'stopping'.

(72) 'vacuum' [dætjum]

/v/ → [d]

Root [+consonantal]

Laryngeal

[+voice]

Oral Cavity

C-Place

[coronal]

The interdental fricatives were also absent from Stacy's inventory. For example, the voiced interdental fricative was realized as a stop in the following example because the features [+continuant], [±anterior] and [±distributed] were not in her feature inventory at the time of testing:

(73) 'these' [dɪd]

/ð/ → [d]

Root [+consonantal]

Laryngeal

Oral Cavity

[+voice]

C-Place

Similarly, the coronal fricatives /s, z/ were absent from Stacy's inventory. In the next example, the coronal fricative /s/ was realized as a coronal stop. This is an example of stopping which involves realizing a fricative as a stop. Stopping results from the lack of acquisition of the feature [+continuant].

(74) 'dress' [dɛt]

/s/ → [t]

Root [+consonantal]

Oral Cavity

C-Place

In other cases, Stacy substituted the segment /ʔ/ for segments that she had not yet acquired. This is illustrated in the following example:

(75) 'nosy' [noʔi]

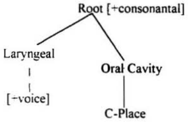
/z/ → [ʔ]

Root [+consonantal]

In this example, /z/ has been realized as [ʔ] due to the position in the word. Here, /z/ was not in word initial position; if it were in word initial position [d] would be an available substitute. As can be seen in this diagram, the target features [+voice], C-Place features and [+continuant] are missing from the representation. The only relevant feature for the glottal stop is [+consonantal]. Since the glottal stop /ʔ/ has such a simple structure, it is a common default for segments that have yet to be acquired. The alveopalatal fricatives were also not found in Stacy's speech sample. This is illustrated in the following example:

(76) 'shoe' [du]

/ʃ/ → [d]

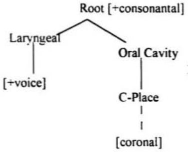


In this example as in the previous examples, the target segment is not produced as Stacy did not have the feature [+continuant] in her inventory. Additionally, the feature [+voice] was inserted; the resulting stop is [+voice] while the target fricative is [-voice]. This may be voicing assimilation due to the following vowel.

There were also no affricates present at the time of testing due to the fact that the feature [±continuant] was not present in Stacy's inventory. Both the voiced and voiceless alveopalatal affricates were absent. The following example illustrates this using the voiced alveopalatal affricate /ʤ/:

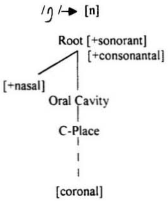
(77) 'juice' [dut]

/ʤ/→ [d]



Stacy had acquired the feature [+nasal], as all target nasals were produced correctly with the exception of /ŋ /. This segment was not missing due to lack of the feature [+nasal] but to the absence of the C-Place feature [dorsal]. Graham was missing this segment for a different reason: he had not acquired coda consonants and this segment only occurs in syllable and word final positions. However, Stacy had coda consonants at the time of testing. The following is an example target word containing the segment /ŋ/:

(78) 'driving' [daɪdɪn]



As can be seen in this example, because Stacy had no [dorsal] feature, she inserted a default [coronal] feature to fill in structure under the bare C-Place node, resulting in the production of a [coronal] nasal.

Stacy had both /w/ and /j/ in her inventory, indicating that she had acquired the feature [±approximant].

The liquid segments /l/ and /r/ were not found in Stacy's inventory. Their absence can be attributed to the fact that the feature [±lateral] had yet to be acquired. /l/ was sometimes replaced by [w] and in other cases it was deleted. Similarly, /r/ was not found in Stacy's inventory and was either replaced with [w] or was deleted. The feature [+consonantal] had not been established for these segments and they were therefore replaced by segments which are [+approximant].

In summary, Stacy's feature geometry was limited at the time of testing. The Root node feature [±lateral] was missing as were the Oral Cavity feature [+continuant] and the C-place feature [dorsal]. In addition, the [±anterior] and [±distributed] had not been acquired at the time of testing.

4.2.2 Prosodic analysis

For the prosodic analysis of both Graham and Stacy data, detailed statistics have not been performed due to the small, qualitative sample size. For example, only one CCVC syllable template was targeted by the study.

Stacy's prosodic tier was found to be more advanced than her segmental tier. This is reflected by the fact that she matched the 63 adult target words for the number of syllables present in 60 (95.2%) of her productions. These results are very different from those seen with Graham, which supports the hypothesis that the development of different tiers is independent.

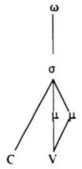
4.2.2.1 Syllable and word template inventory

Stacy's syllable template matched the target form in 55 of the 89 syllables targeted, i.e. 61.8% of the time. The syllables which matched the target templates were of three shapes: 32 (58.2%) of the matching syllables were of the shape CV, 22 (40%) took the form CVC, and CCVC comprised only 1 (1.2%) of the syllable templates matched.

There were 63 words targeted. Stacy's word template matched the targeted template 30 times (47.6%). Of the correctly produced word templates, 17 (56.7%) were monosyllabic and 13 (43.3%) were disyllabic. The correctly produced monosyllabic templates consisted of 14 (46.7%) CVC word shapes and 3 (10%) CV word templates. The disyllabic templates that were produced correctly were CV,CV which made up 8 (26.7%) of the matching word templates, 4 (13.3%) were of the form CV,CVC, and 1 of the matching word templates (26.7%) was of the form CV,CCVC.

In total, Stacy produced 89 syllables. Her syllable inventory consisted of 5 templates and her word inventory consisted of 8 templates. The most frequent syllable template in Stacy's data sample was a CV template, which was produced 54 times; it comprised 58.7% of the syllables produced. It was, however, not the most common word template, though it was produced 13 times as a word template (20.6% of the word templates produced). The following diagram shows the structure of this template:

(79)

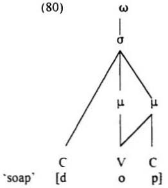


'peach' [p i]

The fact that CV was the most common syllable shape produced is not surprising since it is an unmarked syllable template.

The next most frequent template in Stacy's syllable inventory was CVC which comprised 29.2% of her inventory; it was produced 26 times. This template was the most common word template produced. It was produced 16 times: 25.4% of Stacy's words were of this shape. The CVC word template is the more unmarked form because it is bimoraic and therefore meets the requirements for the minimal prosodic word. This template is illustrated below with an example word from the data:

(80)



The monomoraic syllable consisting of a simple vowel made up 8.7% of the syllables Stacy produced; it was produced 8 times. This is a marked syllable template as it does not have an onset consonant. There were no words produced that took this shape.

In the example provided below, the first syllable of the word is the one which conformed to the template in question:

(81) σ

μ

V

'hilly' [ɪ]

The bimoraic syllable template VC was produced 5 times; it made up 8.7% of the syllables and words produced by Stacy during testing. This template was not produced frequently because although it is bimoraic and therefore meets the requirements for the minimal prosodic word, it does not have an onset and is therefore a marked syllable type. This is illustrated below in the following example:

(82) ω

σ

μ μ

V C

'web' [ɛ b]

4.2.2.1.1 Consonant clusters

There were several word initial consonant clusters in the target words. A few took the shape *stop - liquid* with the stop being /d/ and the liquid being /r/, for example:

(83) 'drive' [daɪ]

As can be seen from this example, in a *stop - liquid* sequence, the cluster was realized as the stop, the least sonorous constituent of the cluster. Another cluster targeted was of the shape *fricative - stop* (/st/), for example:

(84) 'star' [dɑ]

In this example, the stop was retained, again the least sonorous member of the cluster targeted. However, the voicing characteristics were altered; the target stop is [-voice] while the resulting form is [+voice]. This was the result of voicing assimilation to the following vowel. Another targeted cluster shape was *fricative - nasal* (/sn/). Stacy produced this targeted cluster as the nasal, as in the following example:

(85) 'snowing' [noʔwɪn]

Finally, a cluster of the form *fricative - liquid* was targeted (/fr/), as in the following example:

(86) 'frog' [dad]

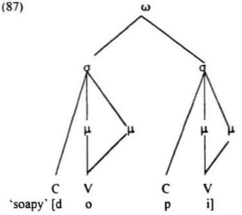
The word was produced with an initial stop. Assuming less marked, less sonorous onsets are more desirable, the fricative would be expected to be produced, not a voiced stop.

However, since Stacy has no [+continuant] feature in her inventory, and therefore no fricatives, a stop is produced instead. The resulting stop is [coronal] because the final consonant that was targeted was [dorsal]; Stacy did not acquire the [dorsal] feature and so she inserted a default [coronal] which assimilated to the word initial stop.

4.2.2.1.2 Disyllabic words

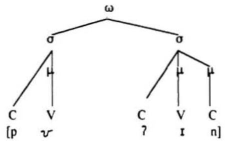
The word template CV,CV, produced 13 times, was the most frequently produced disyllabic shape in Stacy's data; 20.6% of the words produce took this shape. This template is minimally bimoraic and therefore meets the requirements for the minimal prosodic word, making it an unmarked form.

(87)



The disyllabic word template CV,CVC, shown in the following example, made up 11.1% of the word templates found in Stacy's data sample; it was produced 7 times. This form was not as common in her inventory because it has a more complex structure, as it is trimoraic. This template is shown in the next example:

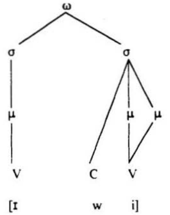
(88)



'pushing'

The disyllabic template V,CV was found to make up 7.9% of Stacy's word template inventory; it was produced 5 times. This form contains a marked syllable template since the first syllable doesn't have an onset. This template is exemplified in the following example:

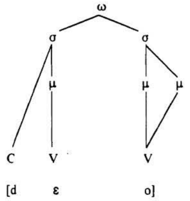
(89)



'hilly'

The disyllabic word template CV,V comprised only 3.2 % of Stacy's word shape inventory; it was produced twice. This form, while bimoraic, is marked, as the second syllable does not have an onset and is therefore a marked syllable form. This template is illustrated in the next example:

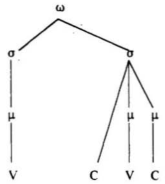
(90)



'chair'

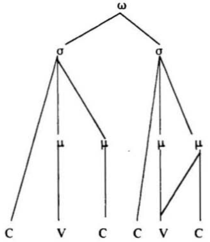
Finally, the word templates V,CVC and CVC,CVC were produced only once; they comprised 1.6% of the word templates produced. These forms are complex since they are trimoraic. These forms are exemplified below in the next two examples:

(91)



'laughing' [æ ʔ ɪ n]

(92)



'vacuum' [d æ t j u m]

In summary, Stacy's syllable and word productions tended toward universally unmarked templates. The syllable template that was the most frequently produced was CV which is the least marked syllable, and the most commonly produced word template was CVC which is the least marked word template. In addition, the syllable templates that were commonly produced had onset consonants. Complex forms, such as words with more than 2 mora and syllables with complex onsets were not produced frequently.

4.2.3 Tier interaction

Analysis of Stacy's tier interaction revealed that her segmental inventory was better developed in some word positions than in others. Stacy's word initial (WI) phonetic inventory is shown in Table 8.

Table 8. Stacy's WI Phonetic Inventory.

	Labial	Labio-dental	Inter-Dental	Alveolar	Alveo-Palatal	Velar	Glottal
Stop Voiceless Voiced	 p b			 t d			
Fricative Voiceless Voiced							h
Affricate Voiceless Voiced							
Nasal	m			n			
Liquid							
Approxi-Mate					j		

As is apparent from Table 8, Stacy's WI inventory did not contain all of the segments that she had acquired at the time of testing. For example, the [+approximate] segment /w/ was not found in WI position. The following diagram represents Stacy's contrastive feature geometry in WI position:

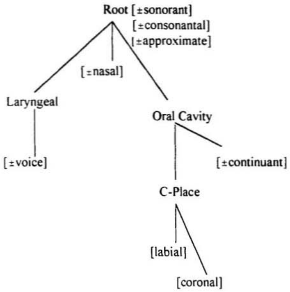


Figure 14. Stacy's WI feature geometry.

Stacy had not acquired the place feature [dorsal] in WI position. All root node features were in place word-initially, as were the features [±nasal] and [±voice]. The feature [±continuant] is included in the geometry. However, since the only [+continuant] segment found was /h/, it is assumed that this feature was barely acquired at the time of testing.

There was only one instance where a segment was targeted in SFWW position. Therefore, SIWW and SFWW positions have been collapsed into word medial (WM) position for this analysis. Table 9 summarizes Stacy's WM phonetic inventory:

Table 9. Stacy's WM Phonetic Inventory.

	Labial	Labio-dental	Inter-Denta l	Alveolar	Alveo-Palatal	Velar	Glottal
Stop Voiceless Voiced	 p b			 t d			 ʔ
Fricative Voiceless Voiced							 h
Affricate Voiceless Voiced							
Nasal	m			n			
Liquid							
Approxi-mate	w				j		

This word position was better developed than Stacy's WI position as the segments /ʔ/, /h/, and /w/ were not produced in WI position but were found in WM position. This differs from Graham's data, since he produced fewer segments in this environment. This suggests that Stacy's prosodic development was more advanced than Graham's whose prosodic development resembles that of a young child, with the most segments being realized in WI position. Stacy's contrastive feature geometry for WM position is illustrated in the following diagram:

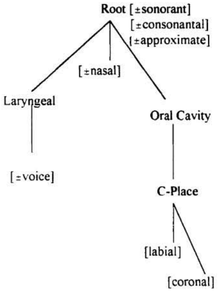


Figure 15. Stacy's WM feature geometry.

Finally, Table 10 summarizes Stacy's WF phonetic inventory:

Table 10. Stacy's WF Phonetic Inventory.

	Labial	Labio-dental	Inter-Dental	Alveolar	Alveo-Palatal	Velar	Glottal
Stop Voiceless Voiced	 p b			 t d			
Fricative Voiceless Voiced							
Affricate Voiceless Voiced							
Nasal	m			n			
Liquid							
Approxi-mate							

This was the least developed segmental position since it was the position with the fewest segments produced.

Stacy's WF contrastive feature geometry is illustrated in Figure 16:

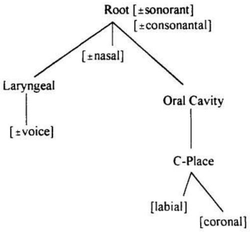


Figure 16. Stacy's WF feature geometry.

In summary, Stacy's prosodic tier was more advanced that her segmental tier allowing her to produce more segments in all prosodic positions. Her segmental inventory was found to be missing velars, all fricatives and affricates, and the liquid segments. Therefore, the features [dorsal], [±continuant], and [±lateral] were not acquired at the time of testing. Her prosodic tier seems more advanced than Graham's. However, her segmental inventory was not as developed as Graham's. Stacy basically had the same core segmental inventory across syllable/word positions while the same was not true for Graham. Graham's segmental inventory was basically only realized word initially. It seems as though Graham's phonological acquisition has centered around the segmental tier while Stacy has concentrated on her prosodic development. These differences in phonological development can be explained by assuming that phonological development is top-down; prosodic development precedes segmental development. Stemberger's model predicts that after prosodic development reaches a certain level, development may take one of two paths: further prosodic development or segmental development. One path involves developing foot and word structure with a limited segmental inventory, as is the case for Stacy, and one involves developing segmental structure within the prosodic environments that have been developed, as is the case for Graham.

5.0 Conclusion

Bernhardt & Stoel-Gammon (1994) suggest that the nonlinear framework allows for independent analysis of the segmental and prosodic tiers as well as for taking into account how the tiers interact during phonological acquisition. Close analysis of Graham and Stacy's phonological errors confirmed that the segmental and prosodic tiers do indeed develop independently, while at the same time, some of the errors resulted from tier interaction.

5.1 Segmental Tier

Analysis of Graham and Stacy's segmental output revealed that features higher in the geometry were better developed than those lower in the geometry. The segments which were acquired by each of the children were those with the least complex structure. For example, neither of the children had significant problems acquiring the root node features [±consonantal], [±sonorant], or [±approximant]. These are the features which define a segment as a consonant, glide or vowel. Conversely, the segments /θ/ or /ð/ were not present in either of the children's inventories. These interdental fricatives have a complex structure. The feature contrast [±distributed] is required for their production. This feature contrast is one of those most deeply embedded in the geometry.

Stacy's segmental inventory was not as developed as Graham's. The features which were acquired at the time of testing were those that were higher up in the geometry. She had only one [+continuant] segment in her inventory, that being [h]. Of all the segments which contain the feature [+continuant], [h] has the simplest structure, as it does not have any place node features. Therefore, it would be expected be acquired early. The C-place feature [dorsal] had not been acquired. While the feature [coronal] did occur as a default, the [-anterior] and [±distributed] coronal features were not present in her inventory. The liquid segments /l/ and /r/ were also missing from Stacy's inventory as they have a complex structure which requires the presence of the contrast [±lateral]. In addition, the fact that both children substituted the glottal stop /ʔ/ for segments they were unable to produce further supports the theory that segments with the least complex structure are acquired earlier than those that have a more complex structure, since the only feature contained in /ʔ/ is [+consonantal].

Gierut, Simmerman, and Neumann (1994) looked at the phonemic inventories of 30 phonologically delayed children. In comparison, both Graham and Stacy's inventories matched the findings of the study. For example, Gierut et al. (1994) found that all of the children in their study used /m n b w/ contrastively. This was true of both Stacy and Graham. Also, none of the children in the study used both /l/ and /r/. This was true of both Graham and Stacy. Gierut et al. (1994) identified four types of phonemic inventories among the 30 children they studied. The simplest inventory, Type I, contained only nasals, stops, and glides. This type of inventory was consistent with Stacy's productions. Type II inventory contained nasals, stops, glides, and fricatives. Graham's phonemic inventory fell into the latter category. It is not surprising that Graham's inventory would be more advanced than Stacy's given the age difference between the two children.

In summary, errors produced could be explained by considering which features were missing from Graham and Stacy's inventories. In general, the more complex segments with the most complex feature structure were more poorly developed than those with a simpler structure, and the features which occur higher in the feature geometry tree were better developed than features lower down.

5.2 Prosodic Tier

Unmarked prosodic structures were prevalent in Graham and Stacy's speech. Bernhardt (1992a) and Fee (1995) propose that the innate syllable template is CV. In Graham's and Stacy's data, the syllable template CV was commonly produced. The fact that CV was commonly produced confirms the position that the presence of an onset is desirable even if not obligatory. Fee suggests that more complex syllable templates, such as those with complex onsets and coda consonants develop later, which explains why these were limited in Graham's and Stacy's productions. Fee also notes that the universally unmarked word template contained one bimoraic foot. This explains why the most common word template in both children's inventories was CVC.

5.3 Tier Interaction

Although nonlinear phonology presupposes tier autonomy, interaction between tiers is also proposed by the framework. Graham and Stacy both demonstrated tier interaction through their output errors. For example, although Graham had a well developed segmental inventory, this was only demonstrated in word initial position. In syllable and word final positions, he only produced [n], [ʔ] (although in one instance the labial fricative [f] was produced). Unlike Graham, Stacy's segmental inventory did not vary across word positions, indicating that her prosodic development was beyond Graham's at the time of testing, but her segmental inventory development was arrested.

5.4 Comparison of Typical and Atypical Phonological Development

Analysis of Graham's and Stacy's errors revealed that their phonological output was comparable to that of the speech of younger children with normally developing phonological systems. For example, as noted earlier, Stoel-Gammon (1991) suggests that children with phonological disorders produce a limited set of segments including stops /p,t,k,b,d,g/, nasals /m,n,ŋ/ and approximants /w,j/. This inventory is almost identical to Stacy's segmental inventory except for the fact that Stacy produced one fricative /h/ and did not have the stops /k,g/ and the nasal /ŋ/. This can be described by assuming that she had not yet developed the feature [dorsal]. The presence of /h/ results from the fact that it is the simplest fricative as it has no place features.

Graham's inventory was more elaborate than the one proposed by Stoel-Gammon. This may be the function of his age. Stoel-Gammon posits that by the age of 2;0 children with normally developing phonological systems usually add fricatives and liquids to their inventories while the development of these segments progresses much more slowly for children with phonological disorders. Graham's inventory contained several fricatives and one of the liquid segments. However, Graham was 9;0 years old at the time of testing, so even though these segments had been acquired at the time of testing, it does not mean that they were acquired in a time frame comparable to normally developing phonological systems. Stoel-Gammon also posits that children with phonological disorders produce a limited number of syllable templates. This was the case with Graham and Stacy. As mentioned above, the unmarked syllable template CV was the most common template in the children's inventories. Similarly, the bimoraic word templates CVC and CVCV were the most common in the two children's inventories. Other more complex templates such as syllables with complex onsets and multisyllabic word templates were rarely produced during testing. The templates produced were the simpler templates which are common in the output of younger children with normally developing phonological systems. The similarities between Graham's and Stacy's phonological output and the output of younger normally developing children suggests that in some respects, phonologically disordered speech is not so much deviant as delayed. Children with disordered phonology are following the same path of phonological acquisition as normally developing children but their acquisition proceeds at a much slower pace. Whether or not it is ever fully acquired is an interesting question for further research.

From Graham's and Stacy's data it can be concluded that phonological acquisition occurs independently across tiers. Also, segments with a simple structure are acquired earlier than those with a more complex structure, and features higher in the geometry are acquired before features that are more deeply embedded. In terms of prosodic acquisition, children tend to favor unmarked syllable and word templates and acquire these before more marked templates. Analysis of the data in the present study indicate that, in some respects, children with phonological disorders have delayed rather than deviant phonological systems; disordered phonological acquisition occurs along the same path as normal phonological but proceeds at a slower rate. This points to the importance of early detection of phonological disorders in children. The earlier the problem is detected, the sooner treatment can begin. If treatment begins at an early age, there is a better chance for reaching treatment goals. The nonlinear framework used in the present study provided a detailed analysis of the delayed phonological systems of Stacy and Graham. Successful methods of phonological analysis, such as the nonlinear analysis used in the present study, are needed to provide detailed descriptions of disordered phonological systems. Clear analyses will lead to a well defined treatment protocol. If children with phonological disorders have delayed phonological acquisition, as indicated in the present study, the question remains as to whether or not with treatment they can eventually fully acquire the phonological system of the target language.

Another question that remains to be answered is why children have delayed phonological systems. For example, are there certain cues that they are missing during acquisition? If this question can be answered, it may tell us something about how normal phonological acquisition takes place.

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