Nonlinear phonological analysis in assessment of protracted phonological development in Mandarin

Utilisation de l'analyse phonologique non linéaire dans l'évaluation des retards du développement phonologique en mandarin

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Editorial process overseen by
Tim Bressmann

Abstract
Nonlinear phonological theories have motivated phonological assessment and intervention practices for English for two decades (e.g., Bernhardt & Stoel-Gammon, 1994; Bernhardt & Stemberger, 2000). Such practices focus on all aspects of the phonological system from word structure to segments (phonemes) and features, highlighting and capitalizing on a client's strengths while addressing his or her needs. The authors and several other international researchers are currently investigating typical and protracted phonological development cross-linguistically, and creating phonological assessment tools for the various languages in the process. The current paper demonstrates a qualitative nonlinear phonological analysis for Mandarin, utilizing data from a Canadian Mandarin-learning child with protracted phonological development.

Abrégé
Les théories sur la phonologie non linéaire sous-tendent les méthodes d'évaluation et d'intervention en anglais depuis deux décennies (p. ex., Bernhardt & Stoel-Gammon, 1994; Bernhardt & Stemberger, 2000). Ces méthodes sont axées sur tous les aspects du système phonologique, de la structure des mots aux segments (phonèmes) et aux traits distinctifs, et mettent en évidence et utilisent les forces d'un client pour cibler ses besoins. Les auteurs et plusieurs autres chercheurs internationaux procèdent actuellement à des études inter-linguistiques sur le développement phonologique typique et les retards du développement phonologique, et créent par le fait même des outils d'évaluation de la phonologie dans diverses langues. Le présent article démontre une analyse qualitative non linéaire de la phonologie en mandarin à l'aide de données recueillies auprès d'un enfant canadien apprenant le mandarin qui a un retard du développement phonologique.

Key words: Mandarin phonological assessment, Mandarin phonological disorders, and Mandarin speech sound disorders

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Nonlinear phonological theories have motivated phonological assessment and intervention methods for English over the past two decades (e.g., Bernhardt, 1990, 1992, 1994a,b; Von Bremen, 1990; Bernhardt & Stoel-Gammon, 1994; Bernhardt & Gilbert, 1992; Edwards, 1995; Bernhardt & Stemberger, 1998, 2000; Bernhardt, Bopp-Matthews, Daudlin, Edwards, & Wastie, 2010) and recently, for German (Ullrich, Romonath & Bernhardt, 2008). The authors and several other international researchers are investigating typical and protracted phonological development in a number of languages, and developing clinical tools in the process. The current paper provides a brief overview of the major aspects of nonlinear theories in clinical application, and demonstrates extensions to Mandarin.

The primary concept of nonlinear phonological theories is the hierarchical organization of the phonological system from phrase and word structure to segments (phonemes) and features (see Figure 1).

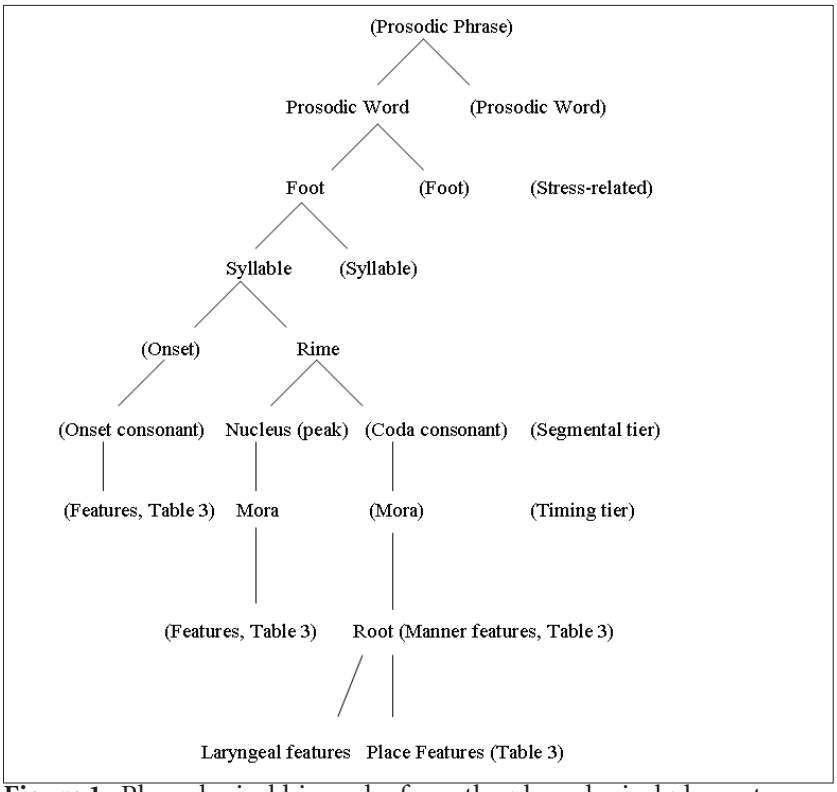

Figure 1 : Phonological hierarchy from the phonological phrase to the features.

Although linguists continue to debate over the exact characterization of phonological organization, the general principles hold that all units of the phonological system are important, and have independent operations and relationships with other aspects of the system. Analysis methods in speech-language pathology based on older theories, such as phonological process analysis, may refer indirectly to different levels of the phonological system. For example, such analyses typically identify patterns affecting syllable structure (cluster reduction, final consonant deletion) versus segments (velar fronting, stopping of fricatives). However, analysis methods based on the nonlinear theories explicitly investigate all the units or domains of a phonological system. In addition, nonlinear analyses explicitly consider the relative autonomy of various units and the interactions between them. While a specific phonological unit (e.g., a feature [+continuant]) may have its own set of constraints, this feature may also be positively or negatively affected when interacting with other units within the phonological system. For example, a client may be able to produce [+continuant] segments (vowels, glides, fricatives and liquids), but only in syllable-final (coda) word position in monosyllables, e.g., *bus*. Through investigation of all the elements of the phonological system, a client's strengths can be identified in addition to their needs. For example, a client may be able to pronounce only a few segments yet be able to produce word structures reasonably well. A 5-year-old child, Colin (pseudonym: Bernhardt and Stemberger, 1998, 2000) was initially able to produce words of up to three syllables with a variety of CV word shapes or sequences including complex ones such as CVCVC and CVCVCVC, yet primarily used only [g], [k], [h], [b] and [a], giving pronunciations such as [gak], [gagak], [baha], [gagagak]. The explicit analysis of his word structures demonstrated to both the clinician and family that, although unintelligible, he had relative strengths in the structural aspects of phonological development: word length, stress patterns and word shape. Small-scale studies applying nonlinear theories have supported the exploitation of the strengths in the system at one level of phonological organization to address needs in other areas (e.g., Bernhardt, 1990, 1992; Von Bremen, 1990; Edwards, 1995; Major & Bernhardt, 1998; Bernhardt & Major, 2005). The equal focus on strengths and needs represents another difference from phonological process analysis, which, being an error analysis, focuses primarily on needs. But comprehensive analysis is often time-consuming. Thus, time-saving methods for nonlinear phonological analysis were developed to increase clinical efficiency: qualitative or scan analyses (Bernhardt & Stemberger, 2000; Ullrich et al., 2008) and computerized quantitative analysis (e.g., Computerized Articulation and Phonology Evaluation System (CAPES), Masterson & Bernhardt, 2001; PHON, Rose & Hedlund, 2008).

The current paper exemplifies a qualitative nonlinear phonological analysis for Mandarin. It is assumed that a speech-language pathologist well-trained in phonetics and phonology can work with a client's family, and/or language support workers, to construct an intervention plan for that client in his or her native language. Facilitative to that enterprise is a standard word list, an organized phonological analysis form and a recording of a native speaker saying the words. Ideally, the clinician would be a native speaker of the child's language, but the reality is that most clinicians are primarily monolingual, with limited knowledge of other languages. The next section describes key aspects

of Mandarin phonology as a basis for the demonstration analysis that follows.

Mandarin (also called Standard Chinese, Guóyǔ, Huáyǔ or Pǔtōnghuà)

In China there are several Chinese dialect/language families[1]: Mandarin, Wu (including Shanghainese, with over 70 million speakers), Yue, Min, Hakka, Xiang and Gan. Mandarin has the largest number of speakers (over 800 million) and is used in government, educational institutions and the media. It serves as a common language for people who speak the different Chinese dialects/languages, many of which are not mutually intelligible. Children receive instruction in Mandarin in the education system from age 3 on and parents also report active teaching of Mandarin at home (Angus & Lei, 2001, p. 2).

The Mandarin language has relatively simple word and syllable structure, an average-sized consonant inventory and a fairly large vowel inventory, with phonemic use of tone. (See also Duanmu, 2000; Bernhardt, Stemberger, Ayyad, Ullrich, & Zhao, in press). As with any language, there are regional variants. The paper focuses on Mandarin, but does discuss Shanghainese briefly in the case example section, because the client described was exposed to both Chinese languages/dialects.

Prosodic Structure: Word Length, Stress, Word Shape and Tone

Mandarin (like other Chinese languages/dialects) has predominantly monosyllabic and disyllabic words, but does have some longer multisyllabic words. According to Duanmu (2000), words of two or more syllables may show trochaic, or stressed-unstressed patterns. Vowel reduction (to schwa) and/or tone neutralization (see below) can occur in the unstressed syllable. There is some disagreement among researchers as to whether Mandarin is a stress-timed language like English (Avery & Ehrlich, 1992), or a syllable-timed language such as Italian or Cantonese (Lin & Wang, 2007; Mok, in press). Mok observes that regional variants of Mandarin may differ in their degree of syllable timing, with some regional variants such as Mandarin spoken in Singapore having fewer unstressed syllables and thus having clearer syllable timing (Mok, in press).

Syllable and word shapes include open (coda-less) syllables such as V, VV, CV, CVV, CVVV (VV = diphthong; VVV = triphthong), and closed syllables such as VC, CVC and CVVC. Sequences of consonants with syllable-final nasals in the first syllable can occur word medially (e.g. [k^ho^{MLM}ŋ.lo^{MH}ŋ 'dinosaur'), but there are no word-initial or final clusters. Duanmu (2000) suggests alternatively that there are syllable-initial consonant-glide clusters with [w], [j] or /ɥ/, and therefore fewer diphthongs and triphthongs with [u], [i] or /y/ as the first vocalic element.

Mandarin has four tones, plus a 'neutral tone' and several tone alternations (tone sandhi). Tones include both level and contour tones (i.e., tones with changes in pitch). Here we give the "tone letters," introduced by Chao (1930), but Duanmu (2000) points out that there is much disagreement among Chinese linguists as to the actual pitch realization of the various tones within and across dialects (Duanmu, p. 211-212).

- Tone 1 (T1): high (H) level /ʂu^H/ 'book'
- Tone 2 (T2): mid-rising (MH) /y^{MH}/ 'fish'
- Tone 3 (T3): mid-low-mid "dipping" /ma^{MLM}/'horse'
- Tone 4 (T4): high-low falling (HL), e.g. /ma^{HL}/'scold'

The neutral tone (0) occurs in a short, unstressed syllable following a stressed syllable (e.g. /^{l}ɚ^{MLM}tuo^0/'ear'); it tends to be 'relatively low' in many cases, and high after Tone 3. (Duanmu (2000) notes that the unstressed syllable in such contexts could be considered 'toneless', p. 224). T3 sandhi, the most common of the tone changes, shows the dipping tone MLM changing to the rising tone MH when it occurs before another dipping tone (i.e. T3→T2/__T3), e.g. for the syllable / ma^{MLM}/→ [ma^{MH}] when preceding another syllable with MLM tone; thus 'ant' is /ma^{MH}ji^{MLM}/, even though the root contained /ma^{MLM}/.

Vowels

Vowels (monophthongs, diphthongs and triphthongs) serve as the tone-bearing units in Mandarin. Although researchers are still investigating the vowels of Chinese dialects both acoustically and in terms of phonetic transcription (Li & Wang, 2003), Mandarin is reported to have eight to nine monophthongs /i y (e) ə ɚ u o ɤ a/. These include distinctions between front, central and back vowels, low, mid and high vowels, rounded and unrounded vowels and tense and lax vowels. Schwa occurs only in unstressed syllables. The /ɚ/ occurs both in isolation (e.g., /ɚ^{HL}/'two') and as a suffix (replacing a nasal consonant, e.g. /kan^H/ as [kaɚ^H], Duanmu, 2000). There are four diphthongs with rising sonority, /ai, ei, ou, ao/ and five with falling sonority, /ia ua uo ie ye/. The four triphthongs are /iao iou uai uei/. (Duanmu (2000) actually treats the initial /i/ and /u/ as glides; there is some disagreement about the final vowel in /uai/, whether it may actually be /e/.) Vowel-feature segment correspondences are listed in Table 1.

Consonants

Standard Mandarin has 24 consonants (see Tables 2 and 3.). All consonants except /ŋ/ occur syllable initially, but only /n/ and /ŋ/ occur syllable finally. In terms of manner of articulation, there are six stops, three nasals, five fricatives, six affricates, two liquids (/l/ and retroflexed /ɻ/)and two glides /w/ and /j/. Place of articulation includes labial, coronal (alveolar, alveopalatal) and dorsal (velar).

1 Research is ambivalent about the word 'language' versus 'dialect' for variants of Chinese. Duanmu (2000) notes that all the variants of Chinese use the same written system, and are very similar grammatically. They do differ phonologically in systematic ways, and Duanmu (2000) claims that, although the variants are at first mutually unintelligible, at least some speakers can learn to understand other variants, given time and exposure. This latter fact and the similarity in the grammatical and written systems suggests that the variants are dialects rather than languages. Here we use dialects/languages or languages/dialects so as to be inclusive of the various perspectives.

Fricatives and affricates can be grooved (strident) or ungrooved, and retroflexed or plain. Duanmu (2000) notes that the Coronal [+anterior] fricatives are produced more in the dental than in the alveolar region, but are still considered to be grooved (strident). In the current paper, we use the dental diacritic (ˌ) to indicate a lack of grooving, rather than an indication of exact place. Consonants differ in terms of the degree of glottis aperture, i.e., they are either aspirated ([+spread glottis]) or non-aspirated ([-spread glottis]). Fricatives are only [-voiced], i.e., [+spread glottis].

Table 1
Vowel-feature correspondences for Mandarin (adapted from Duanmu, 2000)

Vowel	[high]/[low]	[back] (Cor or Dor)	Labial ([+round])
i	[+high]	Dor [-back] & Cor	
y	[+high]	Dor [-back] & Cor	Labial ([+round])
e	[-high][-low]	Dor [-back] & Cor	
ə	[-high][-low]	(Dor [back])[a]	(Labial [round])[a]
ɚ	[-high][-low]	Dorsal [+back]	
u	[+high]	Dorsal [+back]	Labial ([+round])
o	[-high][-low]	Dorsal [+back]	Labial ([+round])
ɤ	[-high][-low]	Dorsal [+back][b]	
a	[+low]	(Dor [back])[a]	

[a]The schwa varies in context in backness and roundness; and thus is unspecified for these features. The /a/ also has several variants, from [+back] to more central. All vowels except schwa are [+tense] (two timing units/moras).
[b]Duanmu (2000) suggests that the unrounded mid back vowel /ɤ/ alternates with schwa in terms of length/syllable stress. The /ɤ/ has two timing units/moras,and occurs in stressed syllables, whereas schwa has one timing unit and occurs in unstressed syllables. Thus, he does not list /ɤ/.

Table 2
Consonant inventory of Mandarin[a]

	Labial	Dental	Retroflex	Alveo-palatal	Palatal	Dorsal (velar)
Stops	p pʰ	t tʰ				k kʰ
Affricates		ts tsʰ	tʂ tʂʰ	tɕ tɕʰ		
Fricatives	f	s	ʂ	ɕ		x
Nasals	m	n				(ŋ)[a]
Approximants	w[b]	l	ɻ		j[b]	

[a]All can occur in syllable-initial position except for /ŋ/. Only the /n/ and /ŋ/ occur syllable-finally.
[b]The glides /w/ and /j/ can be alternately noted as vowels [u] and [i] in diphthongs and triphthongs.

Nonlinear Phonological Analysis for Mandarin

A nonlinear phonological analysis describes forms from all levels of the phonological system (prosodic, segmental, sequences). Clinically, one purpose of the assessment is to determine the client's strengths in terms of phonological development; the other is to determine needs for treatment, if any. Depending on the severity of the problem, the analysis may be brief or extensive. Quantitative analyses are useful for setting baselines and showing change/effectiveness later. However, without computer assistance, they can be time-consuming and moreover, articulation patterns are often sufficiently clear without actually counting. Thus, a qualitative analysis (as is typical in linguistics) is often sufficient.

Both independent (inventory) and relational (match/accuracy) analyses are included. The inventory analysis informs the evaluator about what the client is doing, without regard for the language targets. This is useful, because some forms identified in the inventory can serve as supports for the development of new phonological forms during treatment. The relational analysis describes matches and gaps between the client productions and the target language. Matching forms provide further information about strengths in the system and supports for treatment, whereas gaps indicate potential needs and intervention targets. The case example below demonstrates the various steps of a qualitative analysis for Mandarin. The example begins with the prosodic units, and then proceeds through vowels, consonants and variability/sequence analyses. There is no necessary order of analysis but evaluating prosodic structure and vowels first draws attention to these less frequently evaluated domains in clinical practice.

Case Example

The participant for the case example was a girl (aged 4;1), who was living with her parents and two younger siblings in Canada. The child for this study had a birth weight of just under 7 pounds (i.e., average), although her mother did have gestational diabetes, which can result in heavier than average babies. She had been referred to a preschool health agency because of parental concerns about possibly delayed speech development. There were also concerns about her next-youngest sister in terms of speech development. In terms of language input, her parents reported speaking to her in both Mandarin and Shanghainese in approximately equal amounts. In addition, the child watched a Mandarin DVD for one half-hour daily. (Further information is not available.) This language use accords with Angus (2002)'s claim that speakers from Shanghai often consider both Shanghainese and Mandarin to be important dialects and that parents actively help their

Table 3
Consonant feature-segment correspondences for Mandarin

Consonant	Manner Features	Place Features	Laryngeal Features
p p^{h} [a]	[+consonantal][-continuant]	Labial	[-/+spread glottis][a]
t t^{h}	[+cons][-cont]	Coronal [+anterior]	[-/+spread glottis]
k k^{h}	[+cons][-cont]	Dorsal	[-/+spread glottis]
m	[+cons][-cont][+nasal]	Labial	([+voiced])
n	[+cons][-cont][+nasal]	Coronal [+anterior]	([+voiced])
ŋ	[+cons][-cont][+nasal]	Dorsal	([+voiced])
f	[+cons][+cont]([-sonorant])	Labial [+labiodental]	([+spread glottis])
s	[+cons][+cont]([-sonorant])	Coronal [+anterior] [+grooved]	([+spread glottis])
ts ts^{h}	[+cons][-cont,+cont]([-son])	Coronal [+anterior] [+grooved]	[-/+spread glottis]
ʂ	[+cons][+cont]([-sonorant])	Coronal [-anterior] [+grooved]	([+spread glottis])
tʂ $tʂ^{h}$	[+cons][-cont,+cont]([-son])	Coronal [-anterior] [+grooved]	[-/+spread glottis]
ɕ	[+cons][+cont]([-sonorant])	Coronal [-anterior] [-grooved]	([+spread glottis])
tɕ $tɕ^{h}$	[+cons][-cont,+cont]([-son])	Coronal [-anterior] [-grooved]	[-/+spread glottis]
x	[+cons][-cont,+cont]([-son])	Dorsal	([+spread glottis])
w	[-cons] ([+cont][+son])	Labial	([+voiced])
j	[-cons] ([+cont][+son])	Coronal-Dorsal (palatal)	([+voiced])
l	[+cons] ([+cont][+son])[+lateral]	Coronal [+anterior]	([+voiced])
ɻ	[+cons] ([+cont][+son])	Coronal [-anterior] (+retroflex)	([+voiced])

Note: Parentheses indicate that this feature is predictable for the given target, given other major features of the phoneme, and possibly not a necessary part of the underlying (lexical) representation.
[a]Aspirated obstruents are [+spread glottis] and unaspirated obstruents are [-spread glottis], hence the [-/+spread glottis] notation. These are considered contrasting phonemes (not allophones), but space in the table precludes separate lines.
[b]The table does not indicate [+sonorant], following Bernhardt and Stemberger (2000), where it was noted to be redundant. However, it is to note that nasals and approximants are [+sonorant] and stops and fricatives/affricates are [-sonorant].

children learn Mandarin at home. The child had started learning English in preschool at age 3, but did not use English at home.

The second author, a speech-language pathologist and paeditrician, conducted a speech/language assessment in Mandarin and made the diagnosis of protracted phonological development. (This author is a phonetically trained native speaker of both Shanghainese and Mandarin.) For speech production, a speech sample of 80 single, spontaneous words (constructed to elicit all major aspects of Mandarin phonology) was digitally audio-recorded monaurally with an M-Audio Microtrack recorder and high quality Senheiser wireless lapel microphones. The same author transcribed the sample, with consultation from a trained phonetician. Examples from the word list are provided in the appendix and throughout the analysis below.

Before proceeding to the analysis, major phonological differences between Shanghainese and Mandarin are noted here as a background to interpretation of some of her phonological patterns:

1. Syllables:

Duanmu suggests that Shanghainese does not have a pronounced distinction between stressed and unstressed syllables, whereas Mandarin does distinguish such syllables. However, for both Shanghainese and Mandarin, tones are only associated with the initial stressed syllables lexically, i.e., in underlying representation (2000, p. 230).

2. Tone:

a. According to Jin (1986), Shanghainese has five tones.

b. Shanghainese has a higher frequency of rising tones than Mandarin.

c. Shanghainese low tones are accompanied by murmur (breathy voice: Duanmu, 2000, p 212) and only the T3 of Mandarin appears to be like the [23] contour of Shanghainese, i.e., murmured.

d. Shanghainese tones are sometimes described as akin to registers or pitch accents (Dai, 1991) but are still designated with tone letters.

e. Neutral tones were found less often in a group of Shanghai speakers (Li & Wang, 2003), which accords with the lack of distinction in lexical syllable stress.

3. Consonants:

a. The syllable-final nasal is usually restricted to the velar nasal in Shanghainese (Dai, 1991). Sometimes the nasal is unpronounced and realized as nasalization of the preceding vowel (Ramsay, 1989, p. 91).

b. Shanghainese has voiced obstruents (stops and fricatives) word initially, unlike Mandarin. These voiced obstruents are apparently produced with breathy voice (murmur) and appear to be associated with the tone on the following vowel, i.e., voiced obstruents are associated with low tone or register, and voiceless ones with high tone or register (Ramsay, 1989, p. 91).

c. Shanghainese has no retroflexed consonants. In Li and Wang (2003), Shanghainese-Mandarin adult bilinguals with 'heavy accents' did not produce the retroflexes when speaking Mandarin, although those with less noticeable accents did produce some of the retroflexes accurately.

d. Some syllables may end in glottal stop, unlike in Mandarin (Ramsay, 1989, p. 93).

4. Vowels:

According to Ramsay (1989), Shanghainese has more monophthongs than Mandarin, because of sound changes reducing diphthongs to monophthongs (12 vowels in total instead of nine). For example, /lai/ of Mandarin is often pronounced as [le] in Shanghainese or /ao/ as [ɔ] (Ramsay, 1989, p. 92).

Clinical Analysis Part 1: Initial Overview

In starting a phonological analysis, it can be useful to begin with a short perusal of the data (5-10 minutes, depending on the complexity of the sample), called a "Bird's Eye View" in Bernhardt and Stemberger (2000). This initial overview (Table 4) can help identify (1) obvious strengths of a client's phonological system and (2) further needs for detailed analysis, i.e., targets showing obvious inconsistency or major gaps with respect to the adult language. In Table 4, a filled-in checkbox indicates general match with the adult target, and a blank checkbox and underlining, a general mismatch. Parentheses indicate inconsistent matches.

The overview showed the following:

1. Prosodic structure: Generally a strength. The following examples demonstrate inconsistency in use of (a) syllable-final nasals and (b) monophthong versus diphthongs versus triphthongs, and thus a need for further analysis of positional patterns_ (nasals) and wordshapes.

Word-final nasal and diphthong/monophthong matches:

Target	Child	English
/$t^hai^{HL}ja\eta^0$/ >	[$t^hai^{HL}ja\eta^0$]	'sun'
CVVCVC >	CVVCVC	
/$tsai^{HL}t\c{c}i\Epsilon n^{HL}$/ >	[$dai^{HL}t\c{c}i\Epsilon n^{HL}$]	'goodbye'
CVVCVVC >	CVVCVVC	

Word-final nasal and diphthong mismatches:

/$t\c{c}^hi\Epsilon n^{MH}$/ >	[$t\c{c}^hi\Epsilon i^{MH}$]	'money'
CVVC >	CVVV	

Medial nasal match and mismatches:

/$\c{c}io\eta^{MH}mao^{H}$/ >	[$\c{c}io\eta^{MH}mao^{H}$]	'panda'
/CVVCCVV >	CVVCCVV	
$pi\eta^{MLM}kan^{H}$/ >	[$pi^{MLM}kan^{H}$]	'cookie'
CVCCVC >	CVCVC	

2. Vowels: A relative strength. Inconsistency (as seen in the above examples) suggested a need for further vowel analysis.

3. Consonants: Many matches with the target but inconsistency for most sound classes. Examples in the Appendix and the detailed consonant analysis section show further needs for analysis, particularly for coronal fricatives, affricates and liquids, and unaspirated targets.

4. Variability and sequences: Some variability (noted above) for: (a) word shapes with nasal codas, (b) specific consonant types and (c) vowels. Very few assimilation or metathesis patterns were observed. However, sequences were a relative strength. (*If a client shows variability across words plus assimilation, metathesis, coalescence or dissimilation* for the variable productions, suggesting sequence constraints, further analysis of cross-vowel consonant sequences, CV interactions, or VV/VVV sequences is indicated.) Diphthong sequence analysis was indicated because of metatheses in certain targets.

Detailed Analyses

The following outlines more specifically various aspects of the child's speech production. Possible influences of Shanghainese on Mandarin use are noted.

Table 4
Overview of Case Example

Domain	Specific forms	Strength (General match with target)	Needs further analysis
Prosodic structure	Word length	☑	☐
	Word shape	(☑)	☑
	Tones	☑	☐
	Position-specific patterns[a]	☐	☑ *Nasals in coda?*
	General prosody (rate, pitch, etc.)	☑	☐
Vowels	Overall	(☑)	☑
	Monophthongs?	(☑)	☑ *Some vowel mismatches*
	VV and VVV	(☑)	☑
Consonants	Overall	(☑)	☑
	Manner of articulation	Stops ☑ (Nasals ☑) (Fricatives ☑) (Affricates ☑) (Liquids ☑) (Glides ☑)	☑ All but stops?
	Place of articulation	Labials ☑ Coronals: Dentals ☑ (Alveolars ☑) (Retroflex ☑) (Alveopalatals ☑) (Palatal ☑) (Dorsal ☑)	☑ Coronals?
	Laryngeal status	Aspirated ☑ (Unaspirated ☑)	(☑) Unaspirated?
Variability and sequences	Overall	(☑)	☑ (Vowels? More variable in connected speech?)
	Same word	((☑))	☐
	Same target	(☑)	☑ (Vs, coronal frics. and affricates, word shapes)
	Assimilation or metathesis?	(☑)	☑ (Diphthongs?)

[a]Position-specific patterns include general omission of a target in a word position, or frequent segment (phone) use in one position (such as [t] or glottal stop).
Note: Parents understood about 70% of speech in context, others about 20-30%.

Prosodic Structure: Word Length, Word Shape and Tone

For prosodic structure, it is important to abstract away from the actual segments. The question is whether the consonants and vowels produced help maintain a particular word structure: e.g., for CVC, it only matters that there may be an initial and final consonant and a vowel, not necessarily segments that match the adult target. Table 5 shows a more detailed prosodic structure analysis.

The checkboxes in the first column indicate presence of particular forms (inventory). Mismatches with the language targets ('errors') are underlined. For the adult targets, parentheses around individual Vs or Cs are abbreviations, i.e., (C)VV indicates both CVV and VV. A parenthesis around the entire form (CV(V)C) indicates client inconsistency in matching the target. If there is some obviously frequent form for a particular domain, this can be circled or highlighted in some way. In the current data, no particular form was especially frequent, and thus no highlighting was indicated. Noting the most complex

(maximum) form within a domain shows the client's current potential, even if those complex forms are inconsistent or infrequent. At the bottom of the table is indicated whether the domain is a strength or shows needs, and if there are needs, which ones. The information from this row will be returned to during selection of treatment targets (needs) and treatment strategies (strengths).

As noted in the Overview, prosodic structure was a relative strength across domains for this child. The columns of Table 5 are nevertheless completed for demonstration purposes, even though the Overview indicated a need for analysis of word shape only. Examples in the Overview section, Appendix and Table 5 indicated possible minor needs for development of CV(V)C and CVC. CV(V)(C), as a result of inconsistency in vowel complexity and use of syllable-final nasals. The segmental analysis below further elucidates these needs.

Table 5
Prosodic Structure: Inventory and Matches (mismatches underlined)

Additional Analysis	Word length inventory		Word shape inventory		Tone inventory	
	1 syl	☑	(C)V	☑	T1 – H (high)	☑
			(C)VV	☑	T2 – MH (mid-high)	☑
			(C)VVV	☑	T3 – MLM (mid-low-mid)	☑
			VC	☑	T4 – HL (high-low)	☑
			(CVC)	(☑)	Other:	
			(CVVC)	(☑)		
	2 syl	☑	(C)VCV(V)	☑	Tone Sequences	
			CVVV(C)V(V)	☑	1-0 ☑ -1 ☑ -2 ☑ -3 ☑ -4 ☐*	
			CV(V)CV(V)	☑	2-0 ☑ -1 ☑ -2 ☑ -3 ☑ -4 ☑	
			(C)V(V)CV(V)C	☑	3-0 ☑ -1 ☑ -2 ☑ -4 ☑	
			(CVC.CV(V)(C))	(☑)	4-0 ☑ -1 ☑ -2 ☑ -3 ☑ -4 ☑	
			CVVCCVC	☑	Tone sandhi? 3-3 > 2-3	☑
			CVVC.CVV(V)	☑	Other:	
			Other:		*No data but see 1-4-4-1	
	3+ syl	☑	CV(V)CCVCV)	(☑)	2-4-0	☑
			CVVVCVCCVV	☑	3-2-0	☑
			CVCCVCCVCV	☑	1-4-4-1	☑
Maximum	4-syl		CVCCVCCVCV		1-4-4-1	
Substitution and deletion patterns	No		(Deletion, syl-fin nasals) (Addition of V in some CV(V)C syllables)		No	
More data needed?	No		No		No	
Strength or need?	Strength		Minor needs: CV(V)C, inclusion of coda nasals		Strength	

Segments and Features

The segmental and feature analysis examines all the vowels and consonants of the language, with specific analyses of consonants across word positions. Both independent (inventories) and relational comparisons with the adult target are done. Substitutions for the adult targets are evaluated in terms of target features present, missing or changed. Feature analyses capture generalizations across segments. Analysis may reveal that certain features are present in the system, but not in all the necessary combinations with other features.

Vowels

Only a few targets required further analysis, but for demonstration purposes, all vowels are indicated in Tables 6a to 6c. Table 6a shows monophthongs categorized in terms of their individual features, Table 6b focuses on a specific problematic feature combination (simultaneously co-occurring features) and Table 6c on diphthongs (VV) and triphthongs (VVV). Inventory and relational perspectives are provided, with mismatches underlined and inconsistent matches parenthesized.

Vowels were relative strengths in single word production -- all vowels and their features showed some matches. However, in her connected speech, there appeared to be more variability in vowel production, and in the single-word sample, monophthong mismatches were noted for mid back vowels /o/ and /ɤ/. Substitution patterns included:

a. insertion of a high vowel (diphthongization) as in: /mɤn^{MH}/ > [miɤn^{MH}] ('gate'), /xoŋ^{MH}sɤ^{HL}tə^{0}/ > [xouŋ^{MH}sɤ^{HL}tə^{0}] ('red'); and

b. lowering of /ɤ/ > [a]) as in /kʰɤ^{MH}sou^{0}/ > [kʰa^{MH}sou^{0}] ('cough').

Falling diphthongs /ia/ and /uo/ showed mismatches, with a rising sequence created through:

a. metathesis: /uo/ > [ou], as in /ɚ^{MLM}tuo^{0} /> [ɚ^{MLM}tou^{0}] ('ear'); or

b. addition of a high vowel after the low vowel, as in /tɕʰiƐn^{MH}/ > [tɕʰiƐi^{MH}] ('money').

Shanghainese may have influenced some aspects

of her vowel production, in particular the diphthongs, because Shanghainese has fewer diphthongs than Mandarin. The insertion of a high vowel in /tɕʰiɛnᴹᴴ/ [tɕʰiɛiᴹᴴ] 'money' may be a result of the nasal deletion, another Shanghainese influence, but this is speculative. It is unlikely that vowel metathesis was a direct result of Shanghainese influence.

Consonant Inventory and Word Position

Consonant analyses include: (a) an evaluation of consonant inventory and matches by word position; (b) a substitution analysis of individual consonant features by manner, place and laryngeal status; and (c) evaluation of simultaneous feature combinations. The inventory and match analysis by word position divides targets into true consonants ([+consonantal]) and glides ([-consonantal]), as shown in Table 7.

The rows in Table 7 provide four evaluations: (a) consistent; versus (b) inconsistent matches with the language targets; (c) non-Mandarin substitutions; and (d) consonants or glides missing from the inventory. As noted in the Overview, and further demonstrated in Table 7, the child showed consistent matches for many consonants and glides, but inconsistency concerning coronal fricatives, affricates and /l/. Examples presented in the Overview show inconsistent match for the [Dorsal] nasal /ŋ/ in word-internal syllable-final position, and inconsistent match for the [Coronal] nasal /n/ in word-final position. These inconsistencies may reflect the influence of Shanghainese, where only the velar nasal is used, and even that is sometimes elided. Non-Mandarin substitutions included [d s̪ tsʲ̪ʰ ɕ]. The [d] may also show influence from Shanghainese, which has voiced obstruents. Missing from the word-initial inventory were the affricate /ts/ and retroflex /ɻ/. Missing from the word-medial inventory were the /ts/, /s̪/ and /tʂ/ and /tʂʰ)/. (Further examples are provided in the substitution analysis below.) The lack of retroflexes may reflect the influence of Shanghainese, which has no retroflexes. However, she also used retroflexes on occasion where they do not occur in Mandarin, possibly reflecting over-generalization of a developing category in Mandarin. Because the nasals and the retroflexed fricative and affricates were matched in some word positions, but not others, they would be considered 'positional' (syllable structure) rather than 'segmental' goals.

Table 8 shows all the substitutions (and deletions, indicated with ø) for consonants, divided by manner, place and laryngeal (voiceless) features. The first two columns indicate the adult targets by feature (Column A) and sound class and segments (Column B). Substitutions are entered in a row only if they pertain to the target feature. Some of the substitutions for a given consonant appear in more than one place on the chart, because the consonant shows at least two of manner, place and laryngeal feature substitution patterns.

A summary of the feature substitutions follows with examples.

Table 6a
Vowel Inventory and Match Analysis (mismatches underlined)

Feature or Combination[a]	Vowel Inventory	Strengths/Needs	
Dorsal [+back]	u ☑ (o ☑) (ɤ ☑) a ☑ ə ☑ ɚ ☑	(Strength ☑)	Need ☑
Coronal	i ☑ y ☑ e ☑	Strength ☑	
Dorsal [+high]	i ☑ y ☑ u ☑	Strength ☑	
Dorsal [-high] & [-low]	e ☑ ə ☑ ɚ ☑ (o ☑) (ɤ ☑)	(Strength ☑)	Need ☑
Dorsal [+low]	a ☑	Strength ☑	
Labial [+round]	u ☑ (o ☑) y ☑ ɚ ☑	(Strength ☑)	Need ☑
[-round]	i ☑ e ☑ a ☑ (ɤ ☑)	(Strength ☑)	Need ☑
[+tense]	i ☑ u ☑ y ☑ e ☑ a ☑ (o ☑) (ɤ ☑) ɚ ☑	(Strength ☑)	Need ☑
[-tense]	ə ☑	Strength ☑	

[a]By using the features [Dorsal], [Coronal] (front vowels), and [Labial] (+round vowels), consonant and vowel features can be seen to share place of articulation (Bernhardt & Stemberger, 1998). All vowels use the tongue body and therefore have a [Dorsal] component. Mid vowels are neither [+high] nor [+low] but a combination of [-high] and [-low].
Note. In all tables, parentheses indicate inconsistent matches.

Table 6b
Vowels: Feature Combinations

Vowel Needs for Feature Combinations		Patterns
o ɤ	Dorsal [+back] [-high] [-low]	1. Diphthongization with a [+high] feature: /o/ to [ou] /ɤ/ > [iɤ] 2. Lowering of /ɤ/ > [a]

Table 6c
Diphthongs and triphthongs

VV/VVV	VV, VVV Inventory	Patterns	Strengths/Needs
Rising	ai ☑ ei ☑ ou ☑ ao ☑		Strength ☑
Falling	(ia ☑) ua ☑ (uo ☑) ie ☑ ye ☑ iao ☑ iou ☑ uai ☑ uei ☑	/ia/ > [iai] /uo/ > [ou]	(Strength ☑) Need ☑

Table 7
Consonant and glide inventory and matches

Feature	Word-initial	FW[a]	Medial, Syllable-initial	Word-final
[+consonantal]				
Consistent match	p p^h t t^h k k^h m n f tɕ $tɕ^h$ x	n	p p^h t t^h k m n f s ɕ $tɕ^h$	ŋ
Inconsistent match	s ʂ $tʂ$ $tʂ^h$ ɕ l	ŋ	tɕ l	n
Non-Mandarin substitutions	d ʂ $tʂ$ $tʂ^h$ ɕ		d $tʂ$	
Missing targets	ts ɻ		ts ʂ $tʂ$ $tʂ^h$	
[-consonantal]				
Consistent match	w j			
Inconsistent match			(j)	

[a] FW means Syllable-Final-Within-Word

Note: The word-initial and word-medial inventories show some positional constraints: inconsistency for syllable-final nasals and for use of the retroflexed fricative and affricates (missing word medially but occurring word initially).

1. Liquids /l/ and /ɻ/ and glide /j/: There was not yet a strong contrast between the liquid and glide categories, or within the liquid category, although both /l/ and /j/ sometimes matched. The /l/ sometimes appeared as [j] and the /j/ sometimes as [ɕ] (only word medially).

/jye^{HL}liaŋ^{0}/ > [jye^{HL}jiaŋ^{0}] 'moon'

/ʂua^{H}ja^{MH}/ > [ʂua^{H}ɕa^{MH}] 'brush teeth'

The /ɻ/ appeared consistently as /l/, as in /ɻou^{HL}/ > [lou^{HL}] 'meet.'

2. Coronal fricatives and affricates: As can be seen in Table 8 and the examples below, coronal fricatives and affricates either inconsistently matched, or were absent from the inventory. In terms of substitutions by manner of articulation, coronal fricatives remained fricatives, even if the place or laryngeal features changed, as in:

/suo^{MLM}/ > [ʂuo^{MLM}] 'lock'

/ʂu^{H}/ > [su^{H}] 'book'

However, affricates sometimes lost their [+continuant] (fricative) component as in:

/ts^{h}ai^{HL}/ > [t^{h}ai^{HL}] 'vegetable'

/tʂuo^{H}tsi(ə)^{0}] > [tuo^{H}tʂi^{0}] 'table'

Substitutions by place of articulation showed various changes. The contrast between (dento-) alveolar ([+anterior]) and post-alveolar ([-anterior]) fricatives was not yet well-established. The /s/ showed more consistent matches than /ʂ/, but the two did interchange with one another, as the examples above for /suo^{MLM}/ and /ʂu^{H}/ show. Similarly, the post-alveolar affricates /tʂ(^{h})/and /tɕ/ and fricative /ɕ/ sometimes appeared as dento-alveolars ([+anterior]), whereas the [+anterior] affricate /ts/ sometimes appeared as the [-anterior] [tʂ]. In addition, [+grooved] coronals were often replaced with a [-grooved] consonant.

/tʂ^{H}itʂu^{H}/ > [tʂi^{H}du^{H}] 'spider'

/tsuei^{MLM}pa^{0}/ > [tʂuei^{MLM}pa^{0}] 'mouth'

Finally, although there was a high degree of accuracy for the laryngeal (voiceless) features, the voiced stop [d] sometimes substituted for the voiceless target, as in 'spider' above, and in:

/fei^{H}ɕi^{H}/ > [fei^{H}di^{H}] 'plane'

/tsai^{HL}tɕiЄn^{HL}/ > [dai^{HL}tɕiЄn^{HL}] 'goodbye'

Within the coronal fricative and affricate set for Mandarin, the child showed clear needs for development of manner features (affricates), place features (all) and laryngeal features (primarily affricates).

Variability and Sequences

As indicated in the overview, assimilations, dissimilations, coalescences and metatheses were not observed, except for diphthongs (as noted above under vowels). Thus, for this child, no further analysis was indicated. Other variability was already addressed in the above analyses.

Summary, Goal Selection and Treatment Strategies

The above information is integrated into a final table for analysis, to determine any potential goals and treatment strategies (Table 9).

The general perspective of the nonlinear approach to phonological intervention is to use strong word structures to support new segments and features and vice versa (Bernhardt & Stemberger, 2000). In addition, it is crucial to consider all other aspects of the child's development, in order to set priorities and strategies for intervention. Table 9 first summarizes the strengths and needs across domains of prosodic structure, word position and sequence and features and segments (sub-divided into single features versus feature combinations). Initial goals for Mandarin development are then suggested from this set, with treatment strategies indicated that use strengths to support needs and take other aspects of the child's linguistic system, personality, cognitive development and environmental support into consideration. Finally, a goal order is described which reflects the interactions of phonology with other

Table 8
Consonant substitutions and deletions designated by feature category and word position

Target feature	Target consonants	Word-initial	Medial		Word-final
			SF[a]	SI[a]	
Manner:					
[-consonantal]	Glides w j			(j > ɕ)	
[+sonorant] & [+consonantal]	Liquids l ɻ	(l > j)		(l > j)	
[+lateral]	Lateral l	(l > j)		(l > j)	
[+nasal]	Nasals m n ŋ		(ŋ > ø)		(n > ø)
[-continuant] (& [-nasal])	Oral stops p pʰ t tʰ k kʰ				
[+continuant] (& [-sonorant])	Fricatives f s ʂ ɕ x				
[-continuant], [+continuant]	Affricates ts tsʰ tʂ tʂʰ tɕ tɕʰ	ts > d tsʰ > tʰ tʂ > t, tʰ, d		tʂʰ > tʰ tʂ, tɕ > d	
Place:	Labials				
Labial	p(ʰ) m f w				
Labiodental	f				
Coronal [+anterior]	t tʰ s ts tsʰ n l	(s > ʂ) (l > j) ts > tʂ		(l > j)	(n > ø)
[-anterior]	ʂ tʂ tʂʰ ɕ tɕ tɕʰ ɻ j	(ʂ > s, ʂ) (tʂ, tʂʰ > tʰ, d, tsʰ) (tʂʰ > tʂʰ) (ɕ > ɕ) ɻ > l		ʂ > s tʂ > d tʂʰ > tʰ (tɕ > tʰ, d)	
[+grooved]	s ts tsʰ ʂ tʂ tʂʰ (plus ɻ j)	(ts > d) (ʂ > ʂ) (tʂʰ > tʰ, d, tʂ)		ts > t, tʂ tʂ > d tʂʰ > tʰ	
[-grooved]	ɕ tɕ tɕʰ (plus stops, l, n)				
Dorsal	k g ŋ x w j		(ŋ > ø)	(j > ɕ)	
Laryngeal: [-spread glottis]	Unaspirated p t k ts tʂ tɕ	(ts, tʂ > d)		ts > d (tɕ > d, tʰ)	
[+spread glottis] (asp; [-vc] frics.)	pʰ tʰ kʰ tsʰ tʂʰ tɕʰ f s ʂ ɕ x				

Note. Substitutions are entered only if they apply to the target feature. Parentheses = inconsistent substitution.SF = syllable-final medial; SI = syllable-initial, medial.

factors and the relative strengths in the system.

For this child, there were no high priority prosodic structure needs and therefore no goals for this domain. This indicated that all prosodic structures were available for addressing segment and feature needs, except those with the mismatching vowels and syllable-final nasals (a positional need). Nevertheless, the monosyllable might be the preferred word length in early phases of treatment for such a child, in order to allow specific focus on the particular features/segments in question. When there is apparent variability in connected speech, however, as was the case here, treatment would need to proceed from monosyllables to longer words and phrases. The major needs for this child were coronal fricatives, affricates and liquids, other needs including mid back vowels, the diphthong /uo/ (especially in connected speech where the vowels appeared to vary more), and syllable-final nasals.

The child received treatment over a 10-month period,

Table 9
Summary, Goal Selection and Treatment Strategies

	Prosodic Structure	Word Position or Sequence	Features and Segments
Strengths	Length: ✓ to 4 syl. Word Shape: Most Tone: All	Consonant by position: Most ✓ Sequences: Most ✓ for consonants, vowels, tones	Cons: Stops, labials, dorsals, fric. manner, asp. Vowels: Most ✓ Tones: All ✓
Needs	Length: None Word shape: (CV(V)C), as part of vowel treatment Tones: None	Consonant by position: (a. Syllable-final /n/, /ŋ/) b. Medial /ʂ, tʂ, tʂʰ/ Sequences: /uo/	Consonants: a. Cor frics: [anterior] b. Cor affrics: [-,+cont], [anterior], [-spr glottis] c. Liquids: (l) ɻ: [+/-lat] d. (Glides: /j/) Vowels: Mid back /o/, /ɤ/
Initial goals		a. Medial /ʂ, tʂ, tʂʰ/	Single features: [lateral] Combinations: a. Cor [ant] & [+cont] b. [-,+continuant]: Affric. c. Cor & [-spread glottis] e. Vowels: Mid back
Other factors	Child was exposed equally to Shanghainese and Mandarin, and to some English at preschool. Shanghainese influence was noted for some of the developmental patterns, but not all. She had otherwise normal development and personal-social contexts. A younger sister also had mildly protracted phonological development. Connected speech appeared more variable than the single-word context (general observation).		
Treatment strategies	Tx not indicated (positional, feature)	Observe vowels and coda nasals for spontaneous change after addressing coronal fricatives and affricates	a. Use any structure except those with positional/ sequence needs b. Monosyllables, word-initial (WI), then longer words, phrases
Goal order		2b. Medial [-anterior] fric. /ʂ/ 3b. Medial /tʂ, tʂʰ/	1. Vowels: mid back 2a. [+/-anterior] fric. WI 3a. [-,+continuant] affric. (asp vs unasp), WI (3. [+/-lateral]: (l) ɻ)

with the following goal set and sequence:

1. Vowels: mid back vowels and diphthong /uo/ (because of the apparent greater variability in vowels in connected speech).
2. The fricative [+anterior]/[-anterior] contrast between /s/ and /ʂ/, first word-initially (single feature), and then word medially (positional goal).
3. Affricates, including the sequence [-continuant]-[+continuant], and contrasts in [anterior] (alveolar/ post-alveolar) and [spread glottis] (aspiration).
4. Finally, liquids; because she already used [l] some of the time, the focus was on /ɻ/. (Because she had some exemplars of retroflexes, /ɻ/ was considered an appropriate goal for her age.)

Needs not addressed were /l/, /j/ and the syllable-final nasals.

The family noted that, after targeting the vowels, the child's intelligibility increased noticeably. Following consonant intervention, the coronals also improved, although she continued to produce ungrooved variants some of the time (consistent with her age). In terms of the overall treatment program, her parents reported understanding about 70% of her speech face-to-face within context before treatment, and almost 100% post-treatment. Her grandparents reported understanding about 20% of her speech pre-treatment and about 80% post-treatment when speaking Mandarin to her on the phone from Shanghai.

Conclusion

The objectives of the paper were to outline the major aspects of the Mandarin phonological system and to provide a sample analysis for a child with mild-moderately protracted phonological development based on Bernhardt

and Stemberger (2000) methodology. This particular child additionally showed some influences of Shanghainese. The study was not designed as a treatment study, but observation indicated positive treatment effects. The nonlinear analysis provided (a) confirmation of strengths in many areas of the child's phonological development that could be exploited when addressing needs; (b) a detailed investigation of vowels, which appeared to influence intelligibility notably for this child; and (c) positional and feature information regarding consonant acquisition. For a child with more severely protracted phonological development, more needs would of course be identified across phonological domains, nonlinear analyses providing a framework for detailed analysis within and across the multiple domains (Bernhardt & Stemberger, 2000). However, it is important to note that there are always strengths to be identified in the phonological system, no matter how severely protracted development might be. Through a thorough analysis of the various hierarchical levels of phonological form, these strengths can be identified and used as supports for addressing the needs. More traditional sound-by-sound analyses or phonological process analyses often neglect the positive aspects of development, and furthermore, focus minimally on prosodic structure, giving an incomplete picture, and less specific information for treatment planning.

In an ongoing study, for which these are preliminary data, we will be investigating normal and protracted Mandarin development in Shanghai and Taiwan to develop the data collection and analysis procedures for Mandarin further. Additionally, adaptations of nonlinear analysis procedures are in process with German (Ullrich et al., 2008) and Spanish and are planned for several other languages.

Acknowledgements

The authors gratefully acknowledge the input to this paper from Dr. Yuwen Lai, Dept. of Foreign Languages and Literatures. National Chiao-Tung University, Taiwan, and Dr. Joseph P. Stemberger, Department of Linguistics, University of British Columbia, joint investigator in the cross-linguistic study. In addition, we thank the child and her family for their participation.

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Received: June 25, 2009

Accepted: Mar 12, 2010