Tutorial Article

Optimality theory and assessment of developing and disordered phonologies

Froogh Shooshtaryzadeh

Department of English Language, Imam Khomeini International University, Gazvin, Iran

Abstract

Optimality theory (OT) is a comparatively recent linguistic theory which has been introduced in the early 1990s. OT's description of children's error patterns as patterns that are derived from a hierarchy of conflicting universal constraints has much higher explanatory power than the underlying phonological representations posited by generative phonology which focused only on production. This tutorial article aims to introduce speech clinicians some information about the basic architecture and formalities of OT and highlights some of its advantages over rule-based generative approaches in different linguistic contexts. The article begins with a brief definition of (functional) phonological disorder and explains the basic components of OT and its proposed model of language development in relation to first language acquisition. Finally, the role of OT and standard generative phonology in the assessment of phonological errors produced by children with atypical phonological development is illustrated using empirical data based on Persian language.

Key words: Generative phonology, optimality theory, phonological development, phonological disorder

Introduction

Phonological disorder is the most common speech-language disorder among children which can create major problems in their future life. A child is said to be phonologically disordered (PD) if he/she produces sounds in such a way that is not appropriate to his/her age. For example, if a 5-year-old child produces/d/ instead of/g/, he/she is assumed PD. The experts working with disordered or developing phonologies try to learn more about the nature of phonological disorders to work out more effective intervention plans. To reach this goal, they utilize the knowledge from different fields including linguistics.

Linguistic Approaches

One of the well-known linguistic approaches that speech therapy has already benefited from is standard generative phonology.[1] Generative phonology has attempted to explain a native speaker's phonological knowledge and productions through a system of rules. This framework had some advantages over the preceding descriptive linguistic theories, but it also had some crucial limitations. This point is especially relevant in multilingual contexts such as India that call for in-depth

Address for correspondence:
Dr. Froogh Shooshtaryzadeh,
Department of English Language,
Imam Khomeini International University, Gazvin, Iran.
E-mail: fshude112008@yahoo.com

Access this article online	
Quick Response Code:	Website: www.jisha.org
	DOI: 10.4103/0974-2131.185975

How to cite this article: Shooshtaryzadeh F. Optimality theory and assessment of developing and disordered phonologies. J Indian Speech Language Hearing Assoc 2015;29:13-20.

analysis to uncover the multifaceted factors that affect the linguistic production of the speakers, especially children.

To achieve more comprehensive assessment of the phonological development and disorders in different linguistic contexts, another linguistic theory called optimality theory (OT) was suggested by Prince and Smolensky, McCarthy and Prince.[2-4] This comparatively recent approach attempts to explain the grammatical knowledge of speakers of a given language through a system of constraints. After its emergence in the early 1990s, OT has been widely used in researches related to phonology and phonological development.[5-12] Later, some scholars begin to use OT in the studies related to phonological disorder also.[13-16] These studies along with some others on language development in bilingual contexts have attested OT's higher potentiality than standard generative phonology for the assessment of phonological development and disorders.[17-20] Because of the advantages of OT in offering explanations for aspects of phonological acquisition and phonological disorder in different linguistic contexts, this tutorial article is going to describe the basics of OT for speech clinicians who might be less familiar with this theory.

The Architecture of Optimality Theory

OT theory involves three main components: Lexicon, Generator (Gen), and Evaluator (Eval). These three elements of OT grammar operate one after another when a speaker decides to produce a linguistic form. Figure 1 displays a simple model of how the components cooperate to produce a linguistic structure like the word "lake" during the speech.

As illustrated in Figure 1, Lexicon presents the input, i.e., lexical structure such as the word/lek/"lake." Lexicon includes all the inputs of a language and provides the characteristics of the "input" that is presented to Gen.

Gen provides different outputs (forms) for a certain input presented by the lexicon. To create different candidate outputs, Gen performs different operations on the input, for example, [le] and [we] in the above diagram are created through the deletion of the last segment of the input (/k/) and [let] is produced through fronting process in which the dorsal consonant/k/is changed to the coronal consonant/t/. These operations apply freely, optionally, and repeatedly to derive the members of a candidate set, which are all the possible analyses of the input by the language speakers. Therefore, Gen takes the input from the lexicon and creates a variety of outputs through different actions.

Eval assesses the candidates produced by Gen, ranks them and finally selects the best possible output from the candidates. This output, which is the one actually produced by the speaker during his/her speech, is called optimal output. For example, the optimal output in the above diagram is the candidate [lek]. Eval evaluates and ranks the candidates presented by Gen and choose the optimal output among them through constraints.

Constraints

Constraints exert limitations on the outputs presented by Gen. There are two features in constraints that help Eval to work out the optimal output in OT. First, constraints can be violated by candidates and second, constraints display hierarchical rankings. Usually, the candidates that violate the least number of constraints and/or violate the lower-ranked constraints instead of the higher-ranked constraints can be the optimal output. There are two main types of constraints in OT, namely markedness constraints and faithfulness constraints.

- Faithfulness constraints compare candidates produced by Gen with the input. These constraints require input and output forms to be the same. Therefore, if a candidate is not identical to input, for example, segments are deleted, or new segments are inserted, the faithfulness constraints are violated. For example, if a child produces [tæt] for the word cat, the faithfulness constraint IDENT-IO is violated because the dorsal segment/k/is changed to coronal segment/t/
- Markedness constraints need outputs to be unmarked in structure. Unmarked segments are structurally simpler than marked ones, are acquired sooner by children and are more frequent in languages.[21-24] For example, CV syllables are usually unmarked syllable structures in many languages. Markedness constraints reduce structural complexity and the contrasts between words. The incidence of a marked structure in an output means that a markedness constraint is

	Input		Candidates		Output
LEXICON	→ /lek/ →	GEN →	let, wek, lek, le, we, etc.	→ EVAL (constraints)	→ [lek]

Figure 1: A basic model of optimality theory grammar

violated. For example, the word cat if is produced as/kæt/violates a markedness constraint called *[dor].

The constraints used in the current paper are listed in Table 1. The source, definition and examples of satisfaction of each constraint are mentioned in Table 1.

Tableaus

OT displays the constraints, their ranking, and violations in a tableau format. Tableau 1 is a simple example of an OT tableau which illustrates how English word lake/lek/is produced in English-speaking adults. As it is illustrated, all constraints are listed horizontally in the tableau, in a descending ranking from left to right, i.e., the constraint to the left of the tableau is ranked higher than the constraint to the right and dominates the constraints in the right side. Furthermore, a tableau contains input representation and candidate outputs. All candidate outputs are listed vertically and at random in the left side of the tableau under the input box. The candidate output forms, which violate the higher ranked constraint (s), are less optimal (less well-formed) than candidates satisfying the higher ranked constraint (s). The symbol "*" marks a constraint violation, "*!" indicates a fatal violation, and the pointing hand "☞" indicates the optimal candidate.

The basic constraints employed for the production of the lake are displayed in Tableau 1, i.e., the faithfulness constraints IDENT-IO and the markedness constraints *LIQUIDS and *[dor] which are already defined in Table 1. According to OT, in adults' grammar, faithfulness constraints dominate markedness constraints; therefore, faithfulness constraints are ranked higher than markedness constraints in Tableau 1. As it is indicated in the tableau, candidate "a" ([lek]), violates the lower-ranked constraint *LIQUIDS and *[dor]; however, it does not violate the constraints IDENT-IO which is ranked higher than *LIQUIDS. Candidate "b" ([wek]) shows the fatal violation of the higher-ranked constraints IDENT-IO and the violation of lower-ranked constraint *[dor]. Candidate "c" ([wet]) indicates the fatal violation of IDENT-IO twice. As assumed by OT, the candidates that show the fatal violation of the highest ranked constraint cannot be the optimal output. Therefore, [lek] is the optimal output of the input lake/lek/as observed in the adults' production of the word.

One of the important features of OT is that this theory can encompass all the constraints that affect the production of a linguistic form simultaneously in the same tableau, even if the constraints are from different levels.[12] For example, if the production of a phoneme is affected by the constraints from morphological level as well as phonological level, the constraints from morphology will be present in the same tableau with the constraints from phonology. This OT's feature helps one gain a better understanding of bilingual or multilingual children's productions in which the constraints from different languages may affect a child's production in a specific language. However, rule-based generative phonology lacks such an advantage, i.e., it cannot have the rules from different linguistic levels (e.g., phonology, morphology, etc.) in the same derivation.[4]

Model of Language Development in Optimality Theory

OT has its own special approach to first language acquisition and phonological development.

Normally, in the first stages of language development, children's speech is simpler than adults' from different aspects. For example, words produced by a child may

Table 1: Markedness and faithfulness constraints with samples of their satisfaction and violation

Constraints	Definition	Examples
Markedness		
*[dor][25]	No dorsal consonants	cat →/tæt/
*LIQUIDS[26]	No liquids	lake → [wek]
*SPR-GLOTTIS[27]	No aspirated segments are allowed	pill → [bil]
PWFINDEV[28]	Word-final obstruents are voiceless	bag → [bæk]
Faithfulness		
IDENT-IO[29]	Identical feature values for input and output	/kæt/→ cat

*: A constraint violation

Tableau 1: The production of the target word lake/lek/in adult language

Input: lake/lek/	IDENT-IO	*LIQUIDS	*[dor]
a. ☞ [lek]		*	*
b. [wek]	*!		*
c. [wet]	**!		

*: A constraint violation, **: Two violations of the same constraint, *!: A fatal constraint violation the pointing hand, ☞: Shows the optimal candidate

Tableau 2: The production of [wek] for the word lake in child language

Input: lake/lek/	*LIQUIDS	IDENT-IO	*[dor]
a. [lek]	*!		*
b. ☞ [wek]		*	*
c. [wet]		**	

*: A constraint violation, **: Two violations of the same constraint, *!: A fatal constraint violation the pointing hand, ☞: Shows the optimal candidate

have fewer syllables (e.g., banana → [nana]) or less segments (e.g., lake → [le]). In OT's interpretation, children use a simpler form of language because markedness constraints (which reduce structural complexity and the contrasts between words) dominate faithfulness constraints (that need input and output forms to be the same) at the beginning of language development. Tableau 2 exemplifies ranking of constraints in the first stages of phonological development in children.

Comparison between Tableaus 1 and 2, reveals different constraint hierarchies in child and adult grammar because the markedness constraint *LIQUIDS is ranked higher than the faithfulness constraints IDENT-IO in Tableau 2, while it is vice versa in Tableau 1. This ranking leads to the production of the erroneous form [wek] instead of/lek/for the target form lake. To produce the correct forms, children should rerank their initial constraint hierarchy during phonological development. To rerank a constraint hierarchy, the markedness constraints is demoted (sent to a lower rank) to the right side of the faithfulness constraints, i.e. IDENT-IO. In this way, the child's language system gradually approximates to the adults' language system during language development. So far, the basics of OT have been explained. In the next section, application of OT to developing systems is considered.

Assessment of Developing Phonologies

The constraint-based assessment of phonological errors in OT not only illustrates the procedures in which a form is produced by a child, but also explains why that specific output is produced by the child instead of the others. This framework also elucidates the cause of differences in the productions of children with phonological disorder and typically developing children and helps to discover dissimilarities between the internal grammars of these two groups. However, the rule-based generative phonology is not able to perform all these goals. To indicate the OT's higher explicatory power compared with standard generative phonology, the assessment of two examples of phonological errors in standard generative phonology and OT will be presented. The examples are adopted from an unpublished thesis studied on phonological development in Persian children acquiring Farsi.[27]

Devoicing and voicing errors in phonological development

The errors introduced in this part are an example of word-final devoicing by a child with typical phonological development (Elahe, 2;9) and word-final voicing by a child with phonological disorder (Sepanta, 4;6). These consonants are obstruents, i.e., a category of consonants produced by a partial or complete obstruction of the air in the oral cavity. Obstruents are divided into three subcategories, namely, plosives (e.g.,/t, d, p, b/), fricatives (e.g.,/f, v, s, z/), and affricates (ʤ, ʧ). Obstruents normally tend to be devoiced in word-final position and voicing of obstruents in word-final position is an example of the atypical phonological process.[23,30-32] However, this phenomenon has been observed in some PD children. The devoicing and voicing errors are:

- Devoicing the plosive/d/at the end of the word/kilid/"key" by Elahe:
  Target word child pronunciation gloss
  /d/→ [t] in/kilid/→ [kilit] "key"
- Voicing the devoiced plosive/t/at the end of the word/ʒakæt/"jacket" by Sepanta:
  Target word child pronunciation gloss
  /t/→ [d] in/ʒakæt/→ [ʒakæd] "jacket"

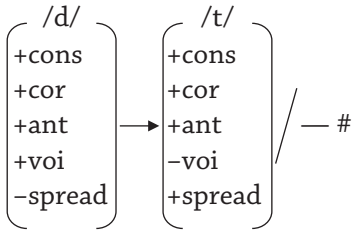
These errors are explained first in standard generative phonology and then in OT framework.

Assessment of phonological processes in generative phonology

Generative Phonology applies phonological rules to describe phonological processes. The above phonological processes can be started with the help of two rules. Rule 1 describes devoicing error made by Elahe in word-final position and Rule 2 describes voicing error made by Sepanta in the same position. The sign "—" shows "where the segment is situated" and "#" means "word boundary."

Rule 1:
/d/→/t/— # (/d/becomes/t/before the word boundary)

Using the phonological features underlying segments, the phonological process is written as follows:



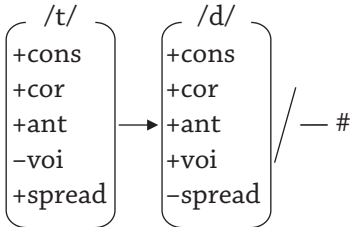
In Rule 1, feature [+cons] "consonantal" means that the segment is a consonant not a vowel; consonants are produced with stricture in the vocal tract while air is passing through the vocal cavity. Feature [+cor] "coronal" means that the segment is produced by raising the tongue

blade onto the hard palate or the teeth. Feature [+ant] "anterior" is related to the sounds which are produced with a constriction around the alveolar ridge. The feature [+voi] "voice" means that the vocal cords vibrate while producing the sound and the feature [+spread] "spread glottis" or "aspirated" describes the sounds which are produced with the vocal cords apart that creates a puff of air like noise in the produced segment.

Both,/d/and/t/are consonantal, coronal, and anterior. However, there are two different features in/d/and/t/, namely voice and spread glottis./d/is [+voi] "voiced" and [–spread] "unaspirated," while/t/is [–voi] "voiceless" and [+spread] "aspirated." It should be noted that voiceless plosives (p, t, k) are usually unaspirated in the word final position in many languages; however, the consonant/t/in Farsi is an exception to this rule and is aspirated even at the end of words.[33] Rule 1 declares that in the devoicing process the underlying voiced unaspirated consonant/d/surfaces as voiceless aspirated consonant/t/in word-final position in the typically developing child Elahe.

Rule 2:
/t/→/d/— # (/t/becomes/d/before the word boundary)

Using the phonological features underlying segments, the phonological process is written as follows:



As expressed in Rule 2, an underlying voiceless aspirated consonant (/t/) surfaces as a voiced unaspirated consonant (/d/) in word final position in a voicing process in the atypical child Sepanta.

As seen in the above rules, standard generative phonology states what happens during a phonological process. However, it does not explain why a phonological process occurs in a child language and why it disappears gradually. It also does not explain why sometimes the errors made by children with phonological disorder are different from those observed in typically developing children.

Assessment of phonological processes in optimality theory

As it is explained in Table 1, OT accounts for the phonological processes through two groups of challenging constraints, namely, markedness constraints and faithfulness constraints. It is assumed that the markedness constraints employed in the above phonological processes are PWFINDEV, *SPR-GLOTTIS and the faithfulness constraint is IDENT-IO. The markedness constraint PWFINDEV "prosodic word-final devoicing" decides that the consonant in the word-final position should be voiceless. *SPR-GLOTTIS "no spread glottis" means that the consonant should be unaspirated. The faithfulness constraint IDENT-IO expects that the features of output segments be identical to the features of input segments. The OT analysis of the phonological errors made by the typically developing and atypical children is presented in OT Tableaus 3 and 4.

Tableau 3 displays the procedure in which Elahe produces the devoiced coronal plosive/t/in the output rather than the voiced coronal plosive/d/in the input.

It is to be noted that in an OT tableau, the constraints to the left of the tableau are ranked higher than the constraints to the right and dominate the constraints on their right side. Moreover, candidate outputs which violate higher-ranked constraints are less optimal than candidates which satisfy the higher-ranked constraints. Therefore, candidate "a" which violates the highest ranked constraint PWFINDEV cannot be the optimal output though it is the most faithful to the input form. Candidate "b" violates the two lower ranked constraints (*SPR. GLOTTIS and IDENT-IO); nevertheless, candidate "b" is selected as the optimal output because it does not violate the highest ranked constraint PWFINDEV. This is why the typically developing child produced the erroneous form [kilit] for/kilid/.

Tableau 4 indicates the uncommon process in which Sepanta produces voiced coronal plosive/d/instead of devoiced coronal plosive/t/in the output.

As exhibited in this tableau, though the employed constraints are the same in Sepanta and Elahe's grammar, the constraint ranking in Sepanta's grammar is different from Elahe's, because in Tableau 4*SPR-GLOTTIS is ranked higher than PWFINDEV and IDENT-IO. Therefore, candidate "a" that violates the highest ranked constraint *SPR-GLOTTIS cannot be the optimal output. However, candidate "b," in spite of violating the constraints IDENT-IO and PWFINDEV, is the optimal candidate because it does not violate *SPR-GLOTTIS.

Comparing Tableaus 3 and 4 reveals why the phonological voicing error occurred in the child with phonological disorder (Sepanta) is different from the common voicing errors observed in Elahe. As it is explained in 4.2,/t/is

aspirated in word-final position in Farsi, so it is more marked than/t/in a similar position in other languages. In Tableau 3, PWFINDEV constraint is ranked higher than *SPR-GLOTTIS and IDENT-IO, which means that the typically developing child Elahe prefers the common devoicing process in which a voiceless plosive, either aspirated or unaspirated, substitutes a voiced plosive. However, as Tableau 4 illustrates, *SPR-GLOTTIS constraint is ranked higher than PWFINDEV and IDENT-IO in Sepanta's grammar, that means he tends to produce unaspirated voiced/d/instead of aspirated voiceless/t/. This tendency can imply Sepanta's problem in producing aspirated sounds in word-final position. This finding can help clinicians make a treatment plan that improves his ability in producing aspirated sounds.

Children's productions gradually become identical to the adults' during phonological development. In OT's interpretation, this phenomenon occurs due to constraint demotion, in which markedness constraints move to the right side of faithfulness constrains. This fact is illustrated in Tableau 5, wherein the markedness constraints *SPR-GLOTTIS and PWFINDEV move to the right side of the faithfulness constraint IDENT-IO that leads to the production of the form [kilid] by children that is the target pronunciation of/kilid/"key."

The assessment of Elahe's and Sepanta's productions in OT framework [Tableaus 3 and 4] has indicated the decisive role of constraints and constraint hierarchies in children's productions. It also illustrates that the differences between the adult's, Elahe's and Sepanta's in Tableaus 3-5 productions are owing to the differences

Tableau 3: Devoicing error in word-final position by Elahe (2;9)

Input:/kilid/"key"	PWFINDEV	*SPR-GLOTTIS	IDENT-IO
a. [kilid]	*!		
b. ☞ [kilit]		*	*

*: A constraint violation, the pointing hand, ☞: Shows the optimal candidate

Tableau 4: Voicing word-final/t/in Sepanta (4;6)

Input:/ʒakæt/"jacket"	*SPR-GLOTTIS	PWFINDEV	IDENT-IO
a. [ʒakæt]	*!		
b.☞ [ʒakæd]		*	*

*: A constraint violation, the pointing hand, ☞: Shows the optimal candidate

Tableau 5: Adult-like constraint hierarchy after constraint demotion in phonological development

Input:/kilid/"key"	IDENT-IO	PWFINDEV	*SPR-GLOTTIS
a. ☞ [kilid]		*	
b. [kilit]	*!		*

*: A constraint violation, the pointing hand, ☞: Shows the optimal candidate

in their constraint hierarchies, i.e., in the organization of their internalized grammar. Moreover, this analysis predicts that the uncommon voicing process in Sepanta's (the child with phonological disorder) productions must originate from his difficulty in aspiration in word-final position. This prediction can help clinicians to come up with a proper treatment plan for him.

What has been discussed so far indicates that generative phonology, which only focuses on the two aspects of underlying representations and surface forms, has certain limitations that are not observed in OT. One of these limitations is related to the analysis of phonological processes in the linguistic contexts marked by multilingualism such as India. For instance, the rule-based system of generative phonology is not able to illustrate the different linguistic elements which interfere with the phonological productions of a child in a multilingual context. However, OT's special architecture makes it possible to indicate all the constraints that can affect a child's production in the same place altogether (i.e., in tableaus), even if they are from different languages used in the same society. This helps clinicians in multilingual societies to gain a comprehensive insight of the factors that affect children's phonological productions and lead them to evolve best strategies to solve specific problems children face in complex linguistic contexts. The assessment of the erroneous productions of typically developing and atypically developing phonologies in OT framework in the preceding sections has also revealed that OT not only can explain phonological processes but also can explain why errors happen and how they are modified during phonological development to approximate adults' production. OT is also able to explain the incidence of uncommon phonological errors in children with phonological disorder and predict the motives behind the errors which help clinicians to pinpoint the child's speech problems and design more focused treatment plans for the children with (functional) phonological disorder. In contrast, generative phonology is neither able to answer the above questions regarding the children's phonological productions nor offer explanations to their changes to account for the differences in typical and atypical phonological development.

Glossary of Technical Terms

Affricates: Phonemes produced through a binary mechanism which begins with an air closure in the mouth and then continues with a gradual release of the air that creates audible friction, like/ʧ/"ch" sound in "cherry" and/ʤ/"j" sound in "judge."

Aspirated: A voiceless consonant (e.g.,/p/,/t/) that is produced with an additional stream of air, which is heard as a "h"-like puff. Aspirated sounds are signified with the phonetic symbol [^{h}], like in English word "pin" [p^{h}in] and Farsi word/pa/[p^{h}a] "foot."

Coronals: Consonants produced by raising the front part of the tongue towards hard palate or teeth, as/t/,/d/,/n/,/z/,/l/and/r/in English.

Devoiced: A normally voiced sound which is produced without vibration of the vocal cords so that it turns out to be wholly or partially voiceless.

Dorsals: Sounds which are articulated with the back of the tongue, such as/k/sound in English word "cold," and Farsi word/kar/"work".

Fricatives: To produce these sounds, the related parts of the oral cavity come very close to each other so that air passes through a very narrow passage which causes the audible friction, as in/s/and/z/.

Glottis: The aperture between the vocal cords (or vocal folds).

Input: The form or interpretation a speaker wishes to produce or convey in a language.

Labials: Consonants articulated by the complete or partial closing of lips, like the sounds/p/,/m/,/w/.

Liquids: Consonants which though may be articulated with a closure, the expiration air can still pass freely and without friction, like English/l/and/r/. They are also capable of being prolonged as a vowel.

Output: The actual linguistic form produced by the speaker to express the intended form or interpretation in a language.

Prosodic word: A sequence of sounds that acts as a unit for some phonological processes, particularly stress or accent. A prosodic word carries a main stress as "cats," "run" and "food" in the sentence "Cats run for the food."

Plosives: Consonants which are produced by the creation of a complete closure in the passage of air from the uvula to the lips, like/b/,/t/,/g/.

Unaspirated: Sounds which are not produced with an additional stream of air, such as/b/,/d/.

Voiced sounds: Sounds produced with the vibration of the vocal cords, like/b/, and/z/.

Voiceless sounds: Sounds produced without the vibration of the vocal cords, as/p/, and/s/.

Voicing: Producing a normally voiceless sound with the vibration of the vocal cords so that it turns into a voiced sound.

Acknowledgment

This paper is an outcome of my doctoral research carried out under the supervision of Prof. Pramod Pandey, Jawaharlal Nehru University, New Delhi, and Duggirala Vasanta, Osmania University, Hyderabad. I would like to thank my supervisors, particularly Prof. Duggirala Vasanta for her valuable comments during writing this article.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Chomsky N, Halle M. The Sound Pattern of English. New York: Harper and Row; 1968.
2. McCarthy JJ, Prince AS. Generalized alignment. In: Booij GE, Van Marle J, editors. Yearbook of Morphology. Dordrecht: Kluwer; 1993a. p. 79-153.
3. McCarthy JJ, Prince AS. Prosodic morphology i: Constraint interaction and satisfaction. ROA-482. New Jersey, USA: Rutgers School of Art and Sciences; 1993b.
4. Prince A, Smolensky P. Optimality Theory: Constraint Interaction in Generative Grammar. Oxford: Blackwell; 1993.
5. Gnanadesikan A. Markedness and faithfulness constraints in child phonology. In: Kager R, Pater J, Zonneveld W, editors. Constraints in Phonological Acquisition. Cambridge: Cambridge University Press; 1995/2004. p. 73-109.
6. Demuth K. Alignment, stress and parsing in early phonological words. In: Bernhardt B, Gilbert J, Ingram D, editors. Proceedings of the International Conference on Phonological Acquisition. Somerville, MA: Cascadilla Press; 1996. p. 113-24.
7. Demuth K. Variation in acquisition: An optimal approach. In: Davis S, editor. Optimality Viewpoints. Bloomington: Indiana University Linguistics Club; 1997. p. 77-88.
8. Dinnsen DA, Barlow JA, Morrisette ML. Long-distance place assimilation with an interacting error pattern in phonological acquisition. Clin Linguist Phon 1997;11:319-38.
9. Goad H. On the status of final consonants in early child language. In: Greenhill A, Hughes M, Littlefield H, Walsh H, editors. Proceedings of the 22nd Annual Boston University Conference on Language Development. Somerville, Mass: Cascadilla Press; 1998. p. 269-80.
10. Pater J, Barlow J. A typology of cluster reduction: Conflicts with sonority. In: Skarabela B, Fish S, Do AH, editors. Proceedings of the 26th Annual Boston University Conference on Language Development. Somerville, Mass: Cascadilla Press; 2002. p. 533-44.
11. Bonilha GF. Phonological disorders in the light of constraints ROA-681. New Jersey, USA: Rutgers School of Art and Sciences; 2004.
12. McCarthy JJ. Doing Optimality Theory: Applying Theory to Data. Oxford, UK: Blackwell Publishing Ltd.; 2008.
13. Barlow JA. Optimality theory and the assessment and treatment of phonological disorders. Speech Lang Hear Serv Sch 2001;32:242-56.

14. Dinnsen DA, O'Conner KM. Implicationally related error patterns and the selection of treatment targets. Lang Speech Hear Serv Sch 2001a; 32:257-70.
15. Gierut JA, Morrisette ML. The clinical significance of optimality theory for phonological disorders. Top Lang Disord 2005;25:266-80.
16. Stemberger JP, Bernhardt BH. Optimality theory. In: Ball M, Kent R, editors. The New Phonologies. San Diego, CA: Singular Publishing Group; 1997. p. 211-45.
17. Gonzales-Diaz MA. Activation and Inhibition. Control Mechanisms in a Bilingual Brain. An Optimality Theory Modelling. MA Thesis, University Van Amsterdam; 2006.
18. Kovacs AM. Early bilingualism and theory of mind: Bilinguals advantage in dealing with conflicting mental representations. In: Siegal M, Surian L, editors. Access to Language and Cognitive Development. Oxford, England: Oxford University Press; 2012. p. 192-218.
19. Mtenje A. An Optimality Theoretic Analysis of Chichewa Loan Words of Monolingual and Bilingual Speakers of Chichewa; 2010. Available from: http://postamble.org/wp-content/uploads/2011/12/Mtenje.pdf. [Last cited on 2014 Dec 03].
20. Muysken P. Language contact outcomes as the result of bilingual optimization strategies; bilingualism. Lang Cogn 2013;16:731-3.
21. Schane SA. Generative Phonology. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.; 1973.
22. Bernhardt BH, Stemberger JP. Handbook of Phonological Development from the Perspective of Constraint-Based Nonlinear Phonology. San Diego: Academic Press; 1998.
23. Kent RD. The MIT Encyclopedia of Communication Disorders. Cambridge, MA: The MIT Press; 2004.
24. Fikkert P. Acquiring phonology. In: de Lacy P, editor. Handbook of Phonological Theory. Cambridge, MA: Cambridge University Press; 2007. p. 537-54.
25. Smolensky P. On the comprehension/production dilemma in child language. Linguist Inq 1996;27:720-31.
26. Barlow JA, Gierut J. Optimality theory in phonological acquisition. J Speech Lang Hear Res 1999;42:1482-98.
27. Shooshtaryzadeh F. Phonological Disorders in the Acquisition of Farsi and Optimality Theory. Unpublished PhD Thesis, Jawaharlal Nehru University, New Delhi; 2014.
28. Kager R. Optimality Theory. Cambridge: Cambridge University Press; 1999.
29. McCarthy J, Prince A. Faithfulness and reduplicative identity. In: Beckman JN, Dickey LW, Urbanczyk S, editors. Papers in Optimality Theory. University of Massachusetts Occasional Papers in Linguistics. Vol. 18. Amherst, MA: Graduate Linguistics Student Association; 1995. p. 249-384.
30. Dinnsen DA. Context-sensitive underspecification and the acquisition of phonemic contrasts. J Child Lang 1996;23:57-79.
31. Barlow JA, Keare AR. Acquisition of final voicing: An acoustic and theoretical account. In: Farris-Trimble AW, Dinnsen DA, editors. IUWPL6: Phonological Opacity Effects in Optimality Theory. Bloomington, IN: IULC Publications; 2008. p. 81-97.
32. Jungsun K, Chin SB. Fortition and lenition patterns in the acquisition of obstruents by children with cochlear implants. Clin Linguist Phon 2008;22:233-51.
33. Samare Y. The phonetics of the Farsi language. Tehran, Iran: University Publishing Centre; 1992.