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Optimality Theory in Egyptian Arabic Phonological Acquisition

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Abstract

This study investigates phonological acquisition in Egyptian Arabic (EA) within the framework of Optimality Theory (OT). Previous research on EA phonological development has primarily focused on the acquisition of phonemes, syllable structures, phonological processes, and suprasegmental features. However, no study has systematically analyzed these aspects using OT. This paper addresses this gap by examining phonological processes in EA-speaking children aged 2 to 3 years, as documented in previous literature (Omar, 1973; Ammar, 1992, 1999, 2002; Morsi, 2001; Abedelfattah, 2002; Ammar & Rifaat, 2004; Ammar & Morsi, 2006; Maamoun, 2008, 2016) from an OT perspective. The study focuses on three major phonological processes: syllable structure processes, substitution processes, and assimilation. The findings indicate that early phonological development is characterized by the dominance of markedness constraints, which are gradually demoted in favor of faithfulness constraints over time. For instance, in cluster simplification, the markedness constraint *COMPLEX outranks faithfulness constraints such as MAX and IDENT. Similarly, in final consonant deletion, the markedness constraint *C# (which favors open syllables) takes precedence over MAX. The weak syllable deletion process is driven by the ranking of *WEAKSYL above MAX. In substitution processes, such as /r/ deviation, the markedness constraint *TRILL dominates IDENT, leading to the avoidance of the trill sound. Finally, in assimilation, the markedness constraint *SAME MANNER prohibits adjacent phonemes with differing manners of articulation, resulting in assimilation patterns. Furthermore, this paper discusses the clinical implications of OT in diagnosing and treating phonological disorders, emphasizing its potential to inform speech therapy interventions. The study underscores the dynamic nature of phonological acquisition and highlights the relevance of OT in modeling constraint re-ranking during linguistic development.

Keywords: EA Phonological Acquisition, OT, Markedness Constraints, Faithfulness Constraints, Clinical Implications.

"اكتساب النظام الفونولوجى للعامية المصرية فى ضوء نظرية الأفضلية اللغوية"

مستخلص

تستكشف هذه الدراسة اكتساب الأطفال المصريين النظام الفونولوجي للعامية المصرية (EA) من خلال إطار نظرية الأفضلية اللغوية.(OT) ركزت الأبحاث السابقة حول تطور النظام الفونولوجى نفي العامية المصرية بشكل أساسي على اكتساب الفونيمات، وبنية المقطع، والعمليات الفونولوجية، والسمات فوق القطعية، إلا أنه لم يتم تحليل هذه الجوانب بشكل منهجي ضمن إطار نظرية الأفضلية اللغوية. يسد هذا البحث الفجوة البحثية من خلال تحليل العمليات الفونولوجية لدى الأطفال الناطقين بالعامية المصرية في الفئة العمرية من 2 إلى 3 سنوات، كما هو موثق في الدراسات السابقة (عمر، 1973؛ عمار، 1992، 1999، 2002؛ مرسي، 2001؛ عبد الفتاح، 2002؛ عمار ورفعت، 2004؛ عمار ومرسي، 2006؛ مأمون، 2008، 2016) وذلك من منظور نظرية الأفضلية اللغوية. تركز الدراسة على ثلاثة أنماط رئيسية من العمليات الفونولوجية، وهي: عمليات بنية المقطع، وعمليات الإبدال، وعمليات المماثلة الصوتية.

تشير النتائج إلى أن المراحل المبكرة من التطور الفونولوجى تتميز بسيادة القيود الوسمية والتي تخضع تدريجياً لإعادة الترتيب لصالح قيود المحافظة مع تقدم التطور اللغوي. فعلى سبيل المثال، في تبسيط العنقود الصامت ، يحتل القيد الموسوم COMPLEX* مرتبة أعلى من قيود الوفاء مثل .MAX IDENT وبالمثل، في عملية حذف الصوامت النهائية، يتفوق القيد الموسوم #C*(الذي يفضل المقاطع المفتوحة) على القيد .MAX أما عملية حذف المقطع الضعيف، فتحدث نتيجة لهيمنة القيد WEAKSYL* على القيد .MAX في عمليات الإبدال، مثل انحراف النطق عن/r/ ، يهيمن القيد الموسوم TRILL* على القيد IDENT، مما يؤدي إلى تجنب صوت الراء (التكرار اللساني). وأخيرًا، في عمليات المماثلة الصوتية، يمنع القيد الموسوم SAME MANNER*وجود فونيمات متجاورة ذات مخارج نطقية مختلفة، مما يؤدي إلى أنماط مماثلة للمخرج.

بالإضافة إلى ذلك، يناقش البحث الآثار الاكلينيكية لنظرية الأفضلية اللغوية في تشخيص وعلاج اضطرابات اللغة والكلام، مع التأكيد على إمكاناتها في توجيه التدخلات العلاجية للنطق. وتؤكد الدراسة على الطبيعة الديناميكية لاكتساب النظم الفونولوجية وتبرز أهمية نظرية الأفضلية اللغوية في تفسير عمليات إعادة ترتيب القيود أثناء الاكتساب اللغوي.

الكلمات المفتاحية: فونولوجيا العامية المصرية، نظرية الأفضلية اللغوية، القيود الوسمية، القيود المحافظة، التطبيقات الاكلينيكية.

1. Introduction

Phonological theories have primarily focused on three key aspects when describing the acquisition process, whether typical or disordered. The first is to explain universal patterns and generalities in children's phonological systems. This effort began with Jakobson and evolved through Chomsky and Halle's markedness theory and Stampe's Natural Phonology. The second priority, within generative approaches, is to construct a formal theory of phonology that characterizes a child's developing linguistic competence. This theory illustrates how children map underlying representations onto surface realizations through a set of linearly ordered phonological rules. Finally, the third priority is to account for the significance of learnability in phonological acquisition, emphasizing the necessity of a learnability theory to explain the relationship between a learner's input and phonological development.

OT has significantly influenced studies on phonological acquisition (e.g., Boersma 1997; Pierrehumbert 2003) by addressing these three priorities. The premise of OT that grammars differ solely in their ranking of universal constraints has implications for language acquisition, as it constrains the learner's search space and establishes a direct connection between phonological typology and acquisition.

To date, no studies have examined the phonological acquisition of EA through the lens of OT. This paper aims to fill this gap by analyzing common phonological processes in EA and applying OT as an analytical framework. The study focuses on phonological processes exhibited by Egyptian children aged 2 to 3, years as documented in the literature. These phonological processes include syllabic structure processes, substitution processes, and assimilation processes. Additionally, the research evaluates OT's capacity to account for these processes, positioning it as a viable theoretical approach to phonological acquisition. Finally, the paper investigates the clinical implications of OT, by proposing its application in the diagnosis and treatment of phonological disorders.

2. The Architecture of OT

OT, introduced by Prince and Smolensky (2004) and McCarthy and Prince (1993, 1994), has become a significant framework in linguistics, particularly in phonology. Its influence, however, extends beyond phonology into other areas such as sociolinguistics, syntax, and semantics (McCarthy 2008: 1). OT emerged as an alternative to the rule-based model, such as the ones in *SPE* (Chomsky & Halle, 1968), which relied on applying a sequence of linearly ordered rules to analyze linguistic phenomena.

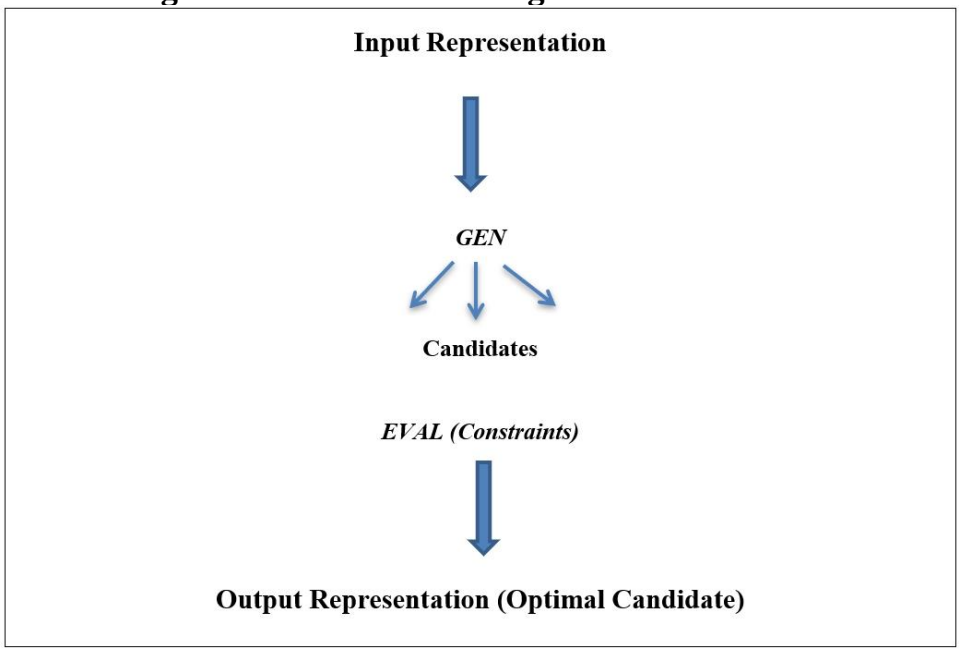
In contrast to the rule-based approach, OT proposes that the connection between an underlying form and its surface form is not derivational. Rather, OT posits that the input is directly mapped to surface forms through a hierarchical evaluation of a set of violable constraints. The key to OT is that mappings are single-step derivations. For a given input, the grammar selects the 'optimal' output form from an infinite set of candidate outputs, all generated by the constraint component.

OT operates in two main stages; (1) the **Generator (GEN)** produces an infinite set of possible output candidates for a given input. Each candidate may violate different constraints to varying degrees. (2) The **Evaluator (EVAL)** scans the candidate set, assessing the well-formedness of each output based on a hierarchy of constraints. The candidate that best satisfies the constraints is selected as the "optimal" output.

The optimal candidate is the one that minimizes violations, adhering as closely as possible to the highest-ranked constraints. Violations of lower-ranked constraints are allowed only if they serve to satisfy more crucial, higher-ranked ones (Kager 1999).

The interaction between these mechanisms is illustrated in Figure 1 below:

Figure 1: Schematic of the grammar within OT



OT constraints are violable, but they only allow violations of the least costly possible, as determined by the hierarchical ranking of the constraints. Some constraints are ranked higher than others in certain languages. This ranking is strict: a higher-ranked constraint takes precedence over all lower-ranked ones. Accordingly, violations of constraints are permitted only if they prevent the violation of higher-ranked constraints.

In OT, constraints are in a relationship of strict domination, meaning that "violation of higher-ranked constraints cannot be compensated for by satisfaction of lower-ranked constraints" (Kager, 1999: 22). An evaluation of output candidates based on a set of ranked constraints can be illustrated in Tableau 1: **Candidate A**, which violates the highest-ranked constraint (**C1**), is ruled out because it incurs a greater cost to a relative well-formedness constraint. Meanwhile, **Candidate C** is eliminated because of its double violation of a single constraint (**C2**), whereas **Candidate B** emerges as the optimal output due to its violation of the lower-ranking constraint **C3**.

The ranking of constraints is represented using the ">>" notation, such as C1 >> C2 >> C3. This notation indicates a transitive hierarchical relationship, where C1 is the highest-ranked and undominated constraint, thereby overriding the subsequent constraints, C2 and C3. In this hierarchy, C2 is ranked higher than C3, establishing a clear precedence in terms of satisfaction. Specifically, the satisfaction of C1 is prioritized over that of C2, and the satisfaction of C2 takes precedence over that of C3.

It is also important to note that the constraints in OT are assumed to be universal and present in all natural languages. Therefore, the only variation between grammars lies in the ranking of these constraints. Violations of the highest-ranked constraints are marked with an asterisk ("*"), while a fatal violation is indicated with an exclamation mark ("!").

Tableau 1: Constraints Interactions

	Constraint1 C1	Constraint 2 C2	Constraint 3 C3
Candidate a	*!		
☞Candidate b		*	*
Candidate c		**!	

In OT, grammatical constraints are categorized into markedness constraints and faithfulness constraints. The interaction between these constraint types models the extent to which marked structures are permitted in a language (Kager, Pater, & Zonneveld).

Markedness constraints, also known as well-formedness or structural constraints, which reflect universal tendencies toward certain structural patterns, such as syllables with onsets. A marked structure (Sm) implies the existence of an unmarked counterpart (Su); for example, a phonological system that includes voiced obstruents implies the presence of voiceless obstruents, but not the reverse. Markedness constraints evaluate candidate outputs, requiring that these forms be unmarked in structure, often based on phonetic

factors (Archangeli & Pulleyblank, 1994).

In contrast, faithfulness constraints, which require that outputs, preserve properties of the input. These constraints prevent processes such as deletion, insertion, and featural changes. Faithfulness constraints govern the input-output mapping. For example, the specific constraint MAX requires that every segment in the input has a corresponding segment in the output (i.e., "no deletion"). Similarly, the DEP constraint expresses "no insertion," while the MAX constraint prevents deletion. Segmental faithfulness is captured by MAX and DEP, while featural faithfulness is represented by the IDENT constraint, which forbids featural changes (no featural changes).

As previously noted, the majority of these constraints are universal, as they are present in most languages (Prince & Smolensky, 2004; Gnanadesikan, 2004; Kager, 1999). However, it is the specific ranking of constraints that distinguishes different languages. Due to their functional impact, a particular constraint may be ranked highly in the hierarchy of one language, while it may occupy a lower position in another language's hierarchy due to its weaker effects.

3. Phonological Acquisition in EA: An OT Perspective

The phonological system of EA has been extensively examined by numerous linguists, including Harrell (1957), Aboul-Fetouh (1969), Abdel-Massih (1975), Broselow (1976), Mitchell (1978), Gary and Gamal-Eldin (1982), Gaber (1986), and Watson (2002). These studies generally concur on the number of phonemes in the EA phonemic inventory, which includes 27 consonantal phonemes. However, slight variations are observed in their descriptions, particularly in the identification of marginal phonemes and the classification of the place of articulation of consonants. Harrell (1957: 25–28) posited that /q/ and /ʒ/ are the only marginal phonemes in the EA phonological system. The phoneme /q/ appears in a limited number of words, such as /qæhıræ/ ‘Cairo’ and /qʊrʔæːn/ ‘Holy Quran’, where it typically shifts to /ʔ/ in other contexts. The phoneme /ʒ/ is found in loanwords, as exemplified by

/gæræːʒ/ ‘garage’. In contrast, Watson (2002: 21) expanded the inventory by adding six more marginal phonemes: four emphatic consonants (/rˤ/, /bˤ/, /mˤ/, /lˤ/) and two loan phonemes (/p/ and /v/). Additionally, Watson’s analysis does not include the uvular place of articulation. In her system, the phonemes /k/, /g/, /x/, and /ɣ/ are categorized under the velar place of articulation, while other analyses assign the fricatives to the uvular category.

Table 1: ***The Phonemic Inventory of EA (adapted from Harrell (1957)).***

	Labial	**Dental**	**Palatal**	**Velar**	**Uvular**	**Pharyngeal**	**Laryngeal**
Stops	b	t tˤ d dˤ		k g	(q)		ʔ
Fricatives	f	s sˤ z zˤ	ʃ (ʒ)		χ ʁ	ħ ʕ	h
Trill		r					
Lateral		l					
Nasal	m	n					
Semivowels	w		j				

The vowel system of EA is less complex than the consonantal system, consisting of five long vowels: /iː/, /eː/, /oː/, /uː/, and /æː/, along with three short vowels: /ɪ/, /ʊ/, and /æ/. Notably, there are no short mid vowels in the dialect. The long mid vowels /eː/ and /oː/ have evolved from Classical Arabic sequences, such as /æ+j/ → /eː/ and /æ+w/ → /oː/.

In terms of syllable structure, EA typically follows the pattern of an obligatory onset, a nucleus, and an optional coda. The language exhibits a relatively restricted range of syllable types, identified by Gamal-Eldin (1967: 12), Abdel-Massih (1975: 25), and Al Ani (1978: 117) as: CV, CVC, CVV, CVVC, and CVCC. CV and CVC are considered light syllables, while CVV, CVVC, and CVCC are heavy syllables that bear primary stress. According to Ammar (2001: 154), only one heavy syllable occurs per word. EA syllables are maximally bi-moraic, and their distribution is subject to certain restrictions. For example, CV and CVC syllables can occur in any position, CVV occurs in pre-final positions, and CVVC and CVCC are restricted to final positions, as noted by Gaber (1986: 15).

Most studies on phonological acquisition such as Demuth (1995); Gnanadesikan (2004); Tesar and Smolensky (1998), (2000); Hayes (2004); and Legendre (2006) have focused on describing the reranking of constraints. Children's early phonology tends to be unmarked, it is generally assumed that, at the initial stages of acquisition, markedness constraints are ranked higher than faithfulness constraints (M >> F). As children grow older and acquire more complex linguistic structures, the markedness constraints that are ranked highly in the target phonology begin to be demoted, while the lower-ranked faithfulness constraints start to be promoted. This gradual process continues until all constraints have reached an "adult-like" position in the hierarchy.

Gnanadesikan (2004) described phonological acquisition as a process of raising faithfulness constraints to approximate the adult grammar more closely by producing more marked forms. OT views the acquisition process as a progression towards positioning markedness and faithfulness constraints in their correct rankings, as they exist in the target language.

Children’s grammars are viewed as markedness constraints which are higher in rank than faithfulness constraints M >> F (Demuth,1995; Granadesikan, 1996; Smolensky, 1996b). For example, when children produce the phonological error pattern known as "fronting," as illustrated in Tableau 2:

Tableau 2: OT Constraints in Fronting

Input /ki/	*Dorsal	IDENT- PLACE
a. Ki	*!	
b. ☞ Ti		*

As we can see, the *Dorsal constraint is ranked above the faithfulness constraint IDENT-PLACE, making the less marked form, Candidate b, the optimal output. Candidate a incurs a fatal violation of the high-ranking *Dorsal constraint, whereas Candidate b satisfies the markedness constraint by substituting the dorsal /k/ with a coronal sound, violating the faithfulness constraint by changing the place of articulation from Dorsal to Coronal. Although a violation occurs, Candidate b's violation of the lower-ranked faithfulness constraint is not fatal, making it the optimal output. In this type of phonological error pattern, children prioritize avoiding dorsal sounds in surface forms over maintaining the correct underlying place of articulation.

Phonological acquisition studies indicate that children's output is significantly less marked than the corresponding adult target forms. Thus, children begin with markedness constraints taking precedence over faithfulness constraints. The learning process involves acquiring the language-specific ranking of markedness and faithfulness constraints by either demoting markedness constraints (as suggested by Tesar and Smolensky, 2000), promoting faithfulness constraints (Gnanadesikan, 2004; Bernhardt and Stemberger, 1998; Stemberger and Bernhardt, 1999), or both (Boersma, 1997; Boersma and Hayes, 2001).

Numerous studies have focused on investigating and documenting the phonological acquisition of typically developing Egyptian children. Notable works include those by Omar (1973), Ammar (1992), Ammar (1999), Morsi (2001), Abedelfattah (2002), Ammar (2002), Ammar & Rifaat (2004), Ammar & Morsi (2006), Maamoun (2008, 2016). A consensus among the majority of these studies

identifies common error patterns and phonological processes observed in children's speech during the critical acquisition period, typically between the ages of 2 and 4 years. These phonological processes are generally categorized into three major types: syllabic structure, substitution, and assimilation. The subsequent section provides an overview of the most prevalent phonological processes in the speech of Egyptian Arabic-speaking children, analyzed from the perspective of OT.

3.1 Syllable Structure Processes

3.1.1 Cluster Simplification

Research on the acquisition of coda clusters in EA has identified three main types of phonological processes observed in children aged two to three years (Maamoun, 2016): cluster assimilation, cluster substitution, and cluster reduction. The developmental trajectory of acquiring a word containing a coda cluster often involves a progression through these processes before achieving the adult target form.

In the early stages, children may exhibit cluster reduction, sometimes resulting in the total deletion of the cluster. As they grow older, they begin to produce one cluster member, either by deleting one of the cluster members, or inserting a vowel (epenthesis) to break the cluster or through cluster assimilation, resulting in the doubling of an identical phoneme. With the continued development of their phonemic inventory, children start producing two-member clusters, though these may not correspond to the target phonemes; instead, more complex articulatory elements are substituted with simpler ones. Ultimately, as their phonemic inventory expands and they acquire a broader range of syllabic structures, children achieve the adult-like production of coda clusters.

The following section provides a brief description of the three phonological processes, along with their subtypes. It also illustrates the developmental stages of acquiring a word with a coda cluster,

examining how constraints interact and are ranked across different ages, culminating in the adult output form.

A. Cluster Reduction

Three patterns are noted in cluster reduction:

i. **Deletion of the whole cluster: the two coda cluster members are deleted as in the word /**diħk/ "laugh" becomes [di]. The constraints that are responsible for this phonological process are presented in tableau 3.

Tableau 3: Constraints of Total Cluster Reduction

Input /diħk/	COMPLEX	MAX
a . [diħk]	*!	
b. ☞ [di]		*

In this example the markedness constraint COMPLEX outranks the faithfulness constraint MAX leading candidate b to be the optimal output for Egyptian children in this early stage. Children follow the constraint COMPLEX by deleting the whole coda cluster from their output. Consequently, this reduces the number of segments within the word, and this violates the lower ranked faithfulness constraint MAX.

ii. **Deletion of one segment** followed by compensatory lengthening as in /tælg/ "ice" becomes [tæ:k]. In this type of partial cluster reduction, a different constraint has been involved as observed in tableau 4.

Tableau 4: Constraints of partial Cluster Reduction

Input / tælg /	COMPLEX	MAX	IDENT
a. [tælg]	*!		
b. ☞ [tæ:k]		*	*

In this example, three phonological processes are applied by Egyptian children: deletion of the most sonorous segment of cluster /l/, compensatory vowel lengthening to keep the weight of the

syllable, and substitution of /g/ by its voiceless counterpart /k/. It is illustrated in tableaux 4 that all these phonological processes occur to avoid violating the markedness constraint COMPLEX. Candidate a is not the optimal output for Egyptian children as it violates the constraint COMPLEX by keeping the coda cluster. Though candidate b violates two constraints: MAX by deleting one phoneme, and IDENT by changing in the voicing feature it still the optimal output. This reflects the rank of these two faithfulness constraints which is lower than the markedness constraint COMPLEX.

iii. **Insertion of a short vowel to break up the cluster** (epenthesis), such as in /baħr/ "sea" becoming [baħil]. In this stage, the Egyptian children phonemic inventory gained many phonemes such as /l/ but still lack the /r/ phoneme that may be substituted by /l/ until the age of four years. Meanwhile, the syllabic structure become more complex as they are now able to produce a disyllabic word but still struggle with producing CVCC. This situation led them to produce three phonological processes within two constraints (DEP & IDENT) to avoid pronouncing CVCC by satisfying the markedness constraints COMPLEX as seen in tableau 5.

Tableau 5: Constraints of Cluster Reduction by Epenthesis

Input /baħr/	COMPLEX	DEP	IDENT
a. [baħr]	*!		
b.☞[ba.ħil]		*	*

Though candidate b violates two faithfulness constraints it is the optimal output for Egyptian children. It violates the constraint DEP by the insertion of the short front vowel /i/ to break the cluster, and the constraint IDENT by the substitution of the feature trill by the feature lateral. For Egyptian children, these two violations consider set the two constraints DEP and IDENT in lower rank than the markedness constraint COMPLEX.

B. Cluster Assimilation

Two main patterns are observed within cluster assimilation:

i. **More sonorous segments assimilate to less sonorous ones**, as in the example where /bærd/ "cold" becomes [bædd].
ii. **Less sonorous segments assimilate to more sonorous ones**, such as in /batˁn/ ("tummy"), which is pronounced as [bann].

These previous examples of cluster assimilation show that when it comes to EA child phonology it is not always the case in which the less sonorous is assimilated to the more sonorous only. Both types of assimilation occur. Egyptian children cannot produce coda cluster of two members of two different sonority values, otherwise it is easier for them to produce coda cluster of two members with identical sonority value. This led either them to double one of the cluster members the most or the least sonorous. The constraints that navigate this process are in tableau 6.

Tableau 6: Constraints of Cluster Assimilation

Input / bærd /	**AGREE(PLACE)**	**IDENT**
a. [bærd]	***!**	
b. ☞ [bædd]		*****
Input / batˁn/	**AGREE(PLACE)**	**IDENT**
a. [batˁn]	***!**	
b. ☞ [bann]		*****

The first example / bærd/ shows a structure that confirms with the sonority scale principle (SSP), while the second example / batˁn/ shows another structure that violates the SSP and in both type of words children apply total regressive assimilation to coda clusters (which means that the markedness constraint *SSP not the one governs the production of cluster by EA children). In both examples, the optimal output are candidates b. EA children can produce CVCC

but with certain limitation; the two-cluster member must be of the same place of articulation. To make cluster pronunciation easier, they implemented regressive total place assimilation. Assimilation is described by a variety of markedness constraints in the literature, such as AGREE(PLACE), which requires neighboring output segments to be defined for the same place feature (Lombardi, 1999; Baković, 2000). The faithfulness constraint MAX is not violated as the number of segments remains the same, otherwise, the constraint IDENT is the one that is violated in candidate b by changing the feature from trill to obstruent in /bard/ and from coronal to nasal in / batˤn/. So that, cluster assimilation by EA children can be analysed as the outranking of the markedness constraint AGREE(PLACE) over the faithfulness constraint IDENT.

C. Cluster Substitution

Cluster substitution is characterized by three distinct patterns:

i. A **more sonorous segment is replaced by a less sonorous one**, as seen in instances of lateralization, devoicing, and stopping. For example:
   - /talg/ “ice” becomes [talt]

In this type of substitution, two phonological processes are involved: fronting and devoicing.

ii. A **less sonorous segment is substituted with a more sonorous one**, as in the case of gliding, as in
   - /baħr/ “sea” becomes [baħl]

The substitution of /r/ by /l/ in the form of lateralization is quite common in EA phonology.

iii. **One segment is substituted by another of similar sonority value**, as observed in phonological process such as lisping and fronting of stops. For example, /xass/ “lettuce” becomes [xaθθ], and /talg/ “ice” becomes [tald]. In the case of / xass /, the fricative sound /s/ is replaced by the fricative /θ/. The

underlying reason for this substitution lies in the feature *strident* associated with the sound /s/, which increases the articulatory complexity of fricatives at this developmental stage. Consequently, children tend to replace /s/ and /z/ with their non-strident counterparts, /θ/ and /ð/. A similar principle applies to fronting. Although Egyptian children can produce stops as a manner of articulation, they do not yet acquire all places of articulation within this manner. Instead, they acquire front places of articulation before back ones. This results in the substitution of back velar sounds, such as /k/ and /g/, with their front counterparts, /t/ and /d/.

These three types of cluster substitution can be analyzed by OT showing how constraints influence cluster substitution without losing any member of the coda cluster.

Tableau 7: Constraints of Cluster Substitution

Input /talg/	**IDENT [DORSAL]**	**IDENT[ANTERIOR]**
a. [talg]	*!	
b. ☞ [talt]		*
Input / baħr/	IDENT[TRILL]	IDENT[LATERAL]
a. [baħr]	*!	
b. ☞ [baħl]		*
Input / libs/	IDENT[STRIDENT]	IDENT [CORONAL]
a. [libs]	*!	*
b. ☞ [libθ]		*

During the acquisition of coda clusters in EA, a child may undergo all the previously mentioned types of phonological processes to master the production of coda clusters. (OT) provides an effective framework for analyzing this developmental process. The acquisition of a single phonological item, such as a coda cluster, often requires the application of multiple phonological processes. Within the framework of OT, this phenomenon is understood as the interaction of various ranked constraints. Let us take the word / baħr/

"sea" as an example of codas cluster acquisition across the age stage of two to three years through constraints' interactions and constraints' ranking. Children may start pronouncing it with total cluster reduction as in example a below:

a. /baɦr/→ [ba]

Here the markedness constraint *COMPLEX outrank the faithfulness constraint MAX. By age they may progress and start pronouncing it with total assimilation as in example b:

a. /baɦr/→ [baɦɦ]

The markedness constraint *COMPLEX is still the highly ranked one and it outranks the faithfulness constraint IDENT.

By getting older, children become ready to the pre final stage, in which the bundle of cluster is produce with substitution to the phonemes that are not acquired yet (the syllabic structure cvcc is acquired but certain phonemes still) as in example c:

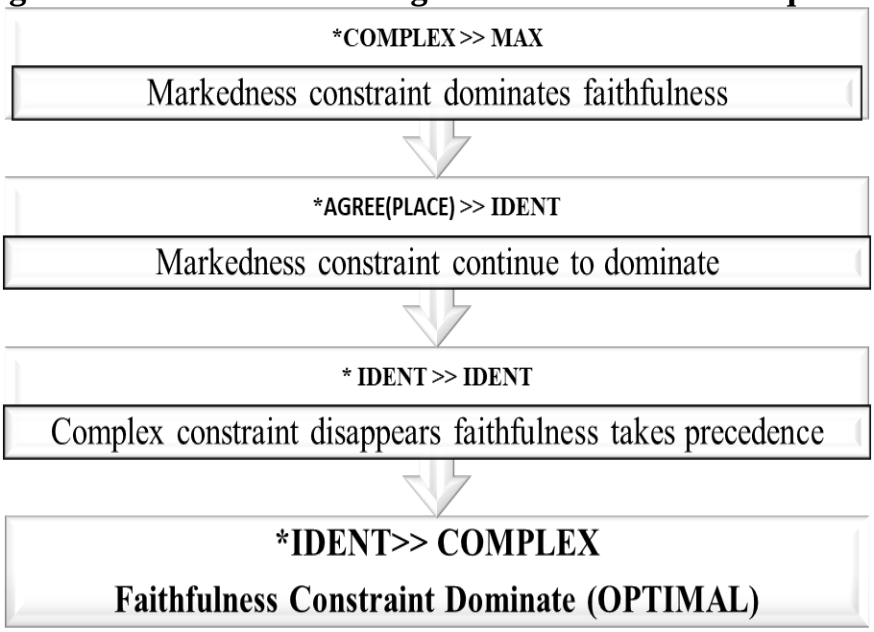
b. /baɦr/→ [baɦl]

Which means that the markedness constraint *COMPLEX is violated and eliminated from the list of constraints. In this phase all interaction is between the different types of the faithfulness constraint IDENT based on the acquired phonemes at this age stage. At the final stage of acquisition, the stage of mastering the syllabic structure cvcc along with its correct phonemes as in example d:

c. /baɦr/→ [baɦr]

Finally, the faithfulness constraint IDENT outrank the markedness constraint COMPLEX, as the optimal output is the one resembles the adult form. Hence, the constraints that are produced by EA children in order to acquire the coda clusters are represented in the following diagram:

Diagram 1: **Constraint Ranking of EA Coda Cluster Acquisition**



This can indicate that the constraint *COMPLEX in Egyptian children phonology is defined as the prohibition of producing coda clusters of two different sonority value members.

3.1.2 Final Consonant Deletion

The occurrence of this phonological process is primarily observed in children aged 2 to 3, though it is characterized by extremely low incidence rates (Morsi, 2001; Maamoun, 2008). In most cases, the deletion impacts liquids such as /l/ and /r/. This process is relatively uncommon in Arabic phonology, contrasting with English, where it is more prevalent and typically persists until approximately age four (Roberts, Bunchinal, & Foolo, 1990).

In cases of final consonant deletion, the syllable transitions from a closed to an open form, which is considered to facilitate pronunciation. The markedness constraint, which discourages closed syllables in the speech of young children, often results in the deletion of final consonants. Consequently, the markedness constraint, denoted as *____C#, takes precedence over the

faithfulness constraint MAX as is seen in tableau 8. This prioritization leads to a violation of the faithfulness constraint MAX, as the number of consonants within syllables is reduced, which is seen as the optimal output. Hence, the hierarchy can be represented as *____C# >> MAX.

Tableau 8: Constraints of Final Consonant Deletion

Input /bæ:b/	*---C#	*MAX
a. [bæ:b]	*!	
b. ☞ [bæ]		*

3.1.3 Weak Syllable Deletion

This phonological process is observed in the speech patterns of Egyptian children, particularly between the ages of 2 and 2.5 years, although its occurrence is relatively infrequent (Ammar and Rifaat, 2004; Maamoun, 2008). In older children, between the ages of three and four, similar patterns have been noted in the study by Ammar and Morsi (2006). Based on OT, this process can be analyzed as observed in tableau 9:

Tableau 9: Constraints of Weak Syllable Deletion

Input /bællo:næ/	*weak Syl	*MAX
a. [bællo:næ]	*!	
b. ☞ [ʔo:næ]		*

In this example, the deletion of the weak syllable while retaining the strong syllable illustrates the markedness constraint *Weak Syllable, which takes precedence over the faithfulness constraint *MAX. Simplifying word pronunciation by reducing the number of syllables, primarily through the elimination of weaker syllables, is the optimal strategy according to this analysis. The hierarchy can be represented as: *Weak Syllable >> *MAX.

3.2 Substitution Processes

3.2.1 /r/ Deviation

The process involves the substitution of /r/ with either /l/ (lateralization) or /j/ (gliding). In the context of EA acquisition, the phonological process of lateralization is observed more frequently in children's speech compared to gliding. This phonological process typically persists until the age of four, as reported by Ammar (1992), Ammar and Morsi (2006), and Maamoun (2008). For instance, the word /ra:s/ ("head") is realized as [la:s].

In both lateralization and gliding, the less sonorous segment /r/ is replaced by a more sonorous one, either /l/ or /j/. This phonological process can be described by OT as illustrated in tableau 10, in which the markedness constraint *trill means the prevention of the feature trill in the surface representation of Egyptian children's speech.

Tableau 10: Constraints of /r/ Deviation

Input //ra:s/	*trill	IDENT
a. [ra:s]	*!	
b. ☞ [la:s]		*

An analysis of this phonological process within the framework of OT necessitates the introduction of a markedness constraint against the trill manner feature (*TRILL). This markedness constraint means the absence of the feature trill (which represents the phoneme /r/) from Egyptian children speech at this age. It is ranked higher than the faithfulness constraint, IDENT which requires that the manner of articulation in the output remains consistent with that of the input. The hierarchy can be represented as:

*TRILL >> *IDENT

Candidate (a) [ra:s] incurs a fatal violation of the high-ranked *TRILL constraint while satisfying the lower-ranked faithfulness constraint IDENT-MANNER. Conversely, candidate (b) [la:s]

avoids violating the high-ranked *TRILL constraint but violates the lower-ranked IDENT-MANNER constraint, thus emerging as the optimal output.

3.2.2 Devoicing

The voiced obstruent is systematically replaced by its voiceless counterpart, a process that persists until approximately the age of four (Ammar and Rifaat, 2004). This phonological phenomenon involves the substitution of the more sonorous sound with one of lower sonority. Research by Maamoun (2008) highlights that this substitution most frequently occurs in the final position, as demonstrated in examples such as /tæ:g/"crown" → [tæ:k], /ze:t/ "oil"→ [se:t], /ruzz/"rice" → [russ], and /lo:z/"almond" → [lo:s].

This process can be explained within the framework of constraint-based phonology, where the markedness constraint *VOICE prohibits the presence of voiced obstruents in the output. For instance, in the case of /ze:t/ → /se:t/, the following evaluation applies in tableau 11:

Tableau 11: Constraints of Devoicing

Input/ze:t/	*VOICE	IDENT VOICING
a. [ze:t]	*!	
b. ☞ [se:t]		*

Candidate (a), which retains the voicing feature in the output, incurs a fatal violation of the high-ranked markedness constraint *VOICE. In contrast, candidate (b) satisfies the *VOICE constraint by replacing the voiced obstruent with its voiceless counterpart but violates the lower-ranked faithfulness constraint IDENT by altering the voicing feature. Based on the ranking of constraints (*VOICE >> IDENT VOICING), candidate (b) is selected as the optimal output.

3.2.3 De-emphasization

The substitution of emphatic phonemes with their non-emphatic counterparts is a well-documented phenomenon in early Egyptian child language development. According to Ammar and Rifaat (2004), this process is prevalent in the speech of children aged 2 to 2.5 years and begins to diminish by the age of three (Maamoun, 2008). Ammar and Morsi (2006) observed that such substitutions rarely occur between the ages of three and four. Examples include: /be:dˤ / "eggs" → [be:t], /ho: dˤ/ "sink:→ [ho:t], /xasˤsˤ / "lettuce" → [xaθθ], and /maʔasˤ/ "scissors" → [maʔaθ], where the more sonorous sound is replaced by a less sonorous counterpart as in tableau 12

Tableau 12: Constraints of De- emphasization

Input /ho: dˤ/	*Emphasis	*IDENT
a. [ho: dˤ]	*!	
b. ☞ [ho:t]		*

The phenomenon can be analyzed within the framework of markedness and faithfulness constraints. The markedness constraint (*Emphasis) inhibits the presence of the emphasis feature in the surface forms of children's speech, thereby overriding the faithfulness constraint (IDENT), which aims to preserve phonological features from the input in the output. When children substitute emphatic phonemes with non-emphatic ones, they prioritize satisfying the markedness constraint, resulting in the selection of non-emphatic forms as the optimal output. This hierarchy is represented as *Emphasis >> IDENT.

*3.2.4 **Stopping***

The phonological process of "stopping" involves the substitution of fricatives to stops. For instance, the word /ʃaraːb/ "socks" is produced as [taraːb]. This process is observed with low frequency with children aged 2 to 3 years. / (Maamoun, 2008).

From the perspective of OT, the high-ranking markedness constraint *FRICATIVES opposes the presence of fricatives in surface representations. The following tableau13 illustrates this constraint interaction:

Tableau 13: Constraints of Stopping

Input /ʃaraːb/	*FRICATIVES	IDENT
a. [ʃaraːb]	*!	
b. ☞ [taraːb]		*

As shown in tableau 13, the markedness constraint *FRICATIVES dominates the lower-ranked faithfulness constraint IDENT, which ensures preservation of the continuant feature. Consequently, stopping occurs as a resolution to mark fricatives in surface forms.

3.2.5 Fronting and Backing

In this process, velar (dorsal) phonemes, such as /k/ and /g/, are replaced with alveolar (coronal) phonemes, /t/ and /d/, respectively. For example, /kælb/ "dog" is produced as [tælb]. While this process is relatively common in English, its frequency is notably lower in Arabic, with occurrences of backing being extremely rare (Morsi, 2001; Maamoun, 2008).

Within the framework of OT, the high-ranking markedness constraint *DORSAL prohibits the production of dorsal phonemes, taking precedence over the faithfulness constraint IDENT. This interaction is depicted in the following tableau 14.

Tableau 14: Constraints of Fronting

Input /kælb/	*DORSAL	IDENT
a. [kælb]	*!	
b. ☞ [tælb]		*

The markedness constraint *DORSAL prohibits dorsal phonemes in surface forms, while the faithfulness constraint IDENT demands that

input features to be preserved in output. Candidate (b), the less marked form, emerges as optimal. Although this form violates IDENT by replacing the dorsal place feature with the coronal one, it satisfies *DORSAL, making it the preferred output. This pattern highlights the marked status of dorsal phonemes in EA child phonology.

3.3 Assimilation

In EA child phonology, assimilation is a prominent process between the ages of 2 and 3. It manifests primarily as total, contiguous, and regressive assimilation. The phoneme /r/ is particularly susceptible to assimilation, likely due to its late acquisition, typically by age 4. Examples include:

- /kursi/ "chair" → [kussi]
- /sursˤaːr/ "cockroach" → [sussaːr]
- /markib/ "boat" → [makkib]
- /marwaħa/ "fan" → [mawwaħa]
- /murgeːħa/ "swing" → [muggeːħa]

Even in cases of progressive assimilation, /r/ remains the most affected phoneme, as seen in examples like /ʔazraʔ/ "planting" → [ʔazzaʔ], /kummitra/ "pear" → [kummitta], and /ʔarnab/ "rabbit" → [ʔannab]. These examples illustrate that Egyptian children often struggle to accurately pronounce two adjacent phonemes with different manners of articulation, particularly when one is a trill.

In OT terms, this phenomenon is driven by the markedness constraint *SAME MANNER, which discourages adjacent phonemes with differing manners of articulation, overriding the faithfulness constraint IDENT. This interaction is shown in tableau 15:

Tableau 15: Constraints of Assimilation

Input /kursi/	*AGREE(MANNER)	IDENT
a. [kursi]	*!	
b. ☞ [kussi]		*

The high-ranking *AGREE (MANNER) constraint leads to assimilation, ensuring that adjacent phonemes share the same manner of articulation, whether fricative, stop, or nasal. This reflects a strategy to avoid the marked trill feature during the phonological acquisition stage. The markedness constraint in assimilation, according to Lombardi (1999), which forces violation of Ident (x) is Agree(x) which adjusts agreement in terms of x between adjacent output segments. X can be a feature such as: voice feature or place feature of a sound segment (McCarthy and Prince (1999). According to Baković (2007) there is a need for ranking Agree(x) above Ident(x) for the sake of guaranteeing assimilation.

4. Results

This study examines the processes of phonological acquisition in Egyptian Arabic-speaking children, with a particular focus on the interplay between markedness and faithfulness constraints within the framework of OT. The findings indicate that phonological development is characterized by the re-ranking of constraints, enabling children to progressively master complex phonological forms. These developmental processes, observed in children aged two to four, illustrate how constraints interact, conflict, and undergo reordering over time to achieve adult-like phonology.

The application of OT to phonological acquisition underscores the dynamic nature of language development and accommodates the description of individual variability. Moreover, the use of constraints in explaining language acquisition contributes significantly to studies of phonological universals. OT provides a dynamic, precise, and economical framework for describing language acquisition by employing a set of violable ranked constraints rather than relying on

a series of fixed, ordered rules to account for each phonological process. For instance, as demonstrated below, variations in outputs, such as consonant clusters, can be explained by referencing the ranking of just two markedness constraints: *Complex and *SSP.

4.1 Constraint Interaction in EA Child Phonology

Initially, markedness constraints often outrank faithfulness constraints in Egyptian children's grammars. This results in outputs that are less marked than adult target forms but violate faithfulness constraints to ensure phonological well-formedness. Key findings include:

In Cluster Simplification OT analysis shows that the markedness constraint *COMPLEX outranks faithfulness constraints such as MAX and IDENT. As children develop, these constraints are re-ranked, allowing the emergence of complex syllable structures as illustrated in the following table 2.

Table 2: ***Constraint Rankings in Coda Cluster Acquisition***

Phonological Process	**Markedness Constraint**	**Rank**	**Faithfulness Constraint**
Cluster Reduction	*Complex	>>	Max
Partial Cluster Reduction (vowel insertion)	*Complex	>>	DEP
Cluster Assimilation	* AGREE(PLACE)	>>	IDENT
Cluster Substitution	IDENT	>>	IDENT

In Final Consonant Deletion & Weak Syllable Deletion Markedness constraints such as */___C# (favoring open syllables) and *Weak Syllable (prioritizing stressed syllables) dominate faithfulness constraints like *Max, resulting in weak syllable deletion and final consonant deletion as it is noted in table 3.

Table 3: ***Constraint Rankings in FCD & WSD***

Phonological Process	Markedness Constraint	Rank	Faithfulness Constraint
Weak Syllable Deletion	*Weak Syllable	>>	*Max
Final Consonant Deletion	*/___C#	>>	*Max

In Segmental Substitution during segment acquisition, substitution processes are governed by markedness constraints, which outrank the faithfulness constraint IDENT. Substitution involves changes in manner, place, or voicing. For example, *Trill leads to /r/ being substituted with /l/ and *Emphasis results in non-emphatic substitutions for emphatic phonemes. More examples are listed in table 4.

Table 4: ***Constraint Rankings of Substitution***

Phonological Process	Markedness Constraint	Rank	Faithfulness Constraint
/r/ Deviation	*Trill	>>	IDENT (manner)
Devoicing	*Voice	>>	IDENT (voicing)
De-emphasization	*Emphasis	>>	IDENT (place)
Stopping	*Fricative	>>	IDENT (manner)
Fronting	*Dorsal	>>	IDENT (place)

In Assimilation Children exhibit total and regressive assimilation, e.g., /kursi/ → [kussi]. The markedness constraint * AGREE(MANNER) prohibits adjacent phonemes with differing manners of articulation, causing assimilation patterns.

5. Clinical Implications

Studies on language development have attested OT's higher potentiality than standard generative phonology for the assessment of phonological development and disorders (Muysken 2013, Gonzales 2006, Barlow 2001, Stemberger ,& Bernhardt 1997). This study demonstrates that phonological development in EA follows a constraint re-ranking trajectory. It emphasizes that phonological

development in children reflects the language-specific re-ranking of constraints rather than isolated error patterns. By understanding the constraints governing phonological development, clinicians can employ OT constraints for diagnosis and assessment. The constraint-based assessment of phonological disorders in OT not only illustrates the environments 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. Constraints based EA phonological development illustrated in tables (2,3,4) can be used as assessment tool in assessing phonological disorders. For example, If EA child at the age of six pronounce the word /ra:s/ "head as /la:s/ clinician can detect that there is a kind of phonological disorder by analyzing his/her speech constraints as in tableau 16 and compared it to the normal constraints in tableau 17

Tableau 16: Production of the Word /la:s/ for /ra:s/ in 6 years EA Child' Speech

Input /ra:s/	*TRILL	IDENT
a. [ra:s]	*!	
b. ☞ [la:s]		*

Tableau 17: Production of the Word /ra:s/ for /ra:s/ in 6 years EA Normal Child' Speech

Input /ra:s/	IDENT	*TRILL
a. ☞ [ra:s]	*!	
b. [la:s]		*

Comparison between tableau 16 and 17 show differences in constraints ranking in child with phonological disorder versus one of the same age of normal phonological development. In this age the norm is the outranking of the faithfulness constraint IDENT over the markedness constraint *TRILL , and this is not the situation in tableau 16 in which the markedness constraint * TRILL is still ranked higher than the faithfulness one. This ranking leads to the incorrect pronunciation of the word /ra:s/ by /la:s/. To correct this

phonological error, clinicians must work on re-ranking child's constraints. To re-rank a constraint hierarchy, the markedness constraints *TRILL must be demoted (sent to a lower rank) to the right side of the faithfulness constraints, i.e. IDENT.

Clinicians may focus on helping children re-rank constraints to align their outputs with adult phonology, rather than correcting individual errors in isolation. For example, if EA children at the age of five has either one or more phonological errors in pronouncing a word like /mærkib/ "boat" and instead of analyzing each error separately, all possible errors can be grouped together in one tableau of constraints as in tableau 18.

Tableau 18 :The Possible Phonological Errors of the Word / mærkib/

Input	*TRILL	*DORSAL	*SAME PLACE	IDENT
a) [mærkib]	*!	!	!	
b) [mælkib]		*!	!	*
c) [mækkib]		*!		*
d) [mættib]				*

Constraint based phonological error analysis is an economical tool of assessment. Clinicians design their treatment plan regarding re-ranking these previous constraint till they reach the optimal goal in which the faithfulness constraint IDENT becomes the highest rank one.

6. Conclusion

This study emphasizes the importance of incorporating theoretical models such as optimality therapy (OT) into practical speech therapy procedures as well as the study of EA phonological development. By using constraints ranking to illustrate normal EA phonological

development, it is possible to illustrate not only phonological processes but also the reasons behind errors and how they are adjusted during phonological development to resemble the production of adults. In order to help clinicians identify the child's speech problems and create more targeted treatment plans for children with (functional) phonological disorder, the architecture of optimality theory makes it easier to explain the prevalence of uncommon phonological errors in children with phonological disorders and forecast the reasons behind the errors.

Constraints in the speech of three-years-old EA children is reranked to make faithfulness constraints like MAX and IDENT dominate, while markedness constraints like *COMPLEX, *Weak Syllable, */___C#, *AGREE(place), *AGREE(manner), *Fricative, *Voice, *Emphasis, and *Dorsal suppressed. EA phonological disorders can be effectively assessed using these kinds of EA norms of constraints.

The results of this research support the null hypothesis, which indicates that all constraints are universal and universally present in the grammars of all languages (Prince and Smolensky 1993,5). Despite constraints universalities in phonological development, however, there seems to be another set of `constraints that are specific to a language or to language groups. In addition to EA, the markedness constraints * DORSAL, *FRICATIVES, and *COMPLEX are universal and exist in children phonology of different languages. For example, they exist in English (Ingram 1980), Cantonese (Dodd 1994), Italian (Bortolini and Leonard (1991), Brazilian Portuguese (Yavas and Lamprecht 1988, Santini (1995), and Spanish (Anderson and Smith 1987). On the other side, differences among constraints may reflect the phonology of the ambient language such as the unique EA markedness constraints *emphatic and * Trill.

Future investigations could broaden this approach by examining the applicability of OT across diverse Arabic dialects and phonological disorders, thereby contributing to a deeper and more inclusive understanding of child phonology and its treatment.

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