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Infants' Acquisition of Korean Consonants: An Optimality-Theoretic Approach*

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Kang, Sung-Ja & Ju-Hyun Jang. 2002. Infants' Acquisition of Korean Consonants: An Optimality-Theoretic Approach. *Linguistic Research 19,* 133-155. This paper aims to give a phonological account of liquids & fricatives and consonant harmony patterns shown in Korean infants. Phonological phenomena in this paper include substitution processes such as stopping of fricatives, nasalization of liquids, stopping of velars, and fronting of palatals and syllable structure processes such as deletion. The data in this study are taken from the spontaneous utterances of ten Korean infants from 26 to 45 months. Based on these data. We also examine the order of the consonantal acquisition of infants and illustrate the order of the substitution processes. The utterances of infants show various consonant harmony patterns such as labio-velar harmony, velar-labial harmony and labio-coronal harmony. For example, when the target is glottal which is triggered by labial, some infants do not show consonant harmony, but other infants do. In this paper, we show that these phenomena are well-captured within the framework of Optimality Theory. **(Kyung Hee University)**

1. Introduction

This paper presents an optimality theoretic account of liquids, fricatives, affricates and consonant harmony and metathesis patterns shown in Korean infants. It will be shown that Optimality Theory

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(Prince and Smolensky 1993, McCarthy & Prince 1995) has advantages in handling various consonant harmony patterns and phonological phenomena in infants' speech.

The phonological phenomena analyzed in this paper include substitution processes, such as stopping of fricatives, nasalization of liquids, stopping of velars, and fronting of palatals as well as processes triggered by syllable structure restriction, such as deletion. The data in this study were elicited from the spontaneous utterances of Korean infants, whose ages ranged from 26 to 45 months. (Kang 2002)

In the speech of Korean infants, liquids and fricatives show interesting phonological phenomena. The intervocalic liquid, /r/ is generally deleted or substituted, but syllable initial liquid, /l/ is substituted. While, syllable initial glottal /h/ is substituted, but intervocalic glottal /h/ is deleted. In order to present an explicit explanation on these phenomena, we will show that this difference can be accounted for straightforwardly within Optimality Theory.

The utterances of Korean infants show various consonant harmony patterns such as labial-velar harmony, velar-labial harmony and labial-coronal harmony. When the target is glottal which is triggered by labial, consonant harmony may appear, or may not appear. These various consonant harmony patterns are analyzed within the framework of Optimality Theory. We will also analyze metathesis between syllables.

2. Acquisition of consonants in Optimality Theory

We describe the process of consonant acquisition and phonological phenomena in Korean infants by adjusting the ranking of Ident constraints and powerful markedness constraints in Correspondence Theory (McCarthy & Prince 1995).

Positional faithfulness in Correspondence Theory is that segments located particular position between input and output should fulfill faithfulness constraint. This positional faithfulness constraint is used to present an explanation on consonant harmony.

Positional Faithfulness constraint is to keep the specific feature in input to output prominently positioned cognitively and phonetically. There exist particular prosodic positions that are most prominent, both cognitively

and phonetically (Beckman 1997a, b). These prominent positions are more likely to retain input feature specifications in the output than non-prominent positions. This positional prominence has been termed positional faithfulness. In order to forge this idea, positional faithfulness constraints that govern the correspondence identity of segments in prominent positions were conceived and introduced (Beckman 1997a, b, Ahn 2000).

2.1 The process of consonant acquisition: Data Analysis of Jeong-yun's and Ji-yun's (Kang 2002)

We analyze the process of variation from consonant harmony to metathesis through constraint hierarchy in optimality theory. We analyze infants' speech. First consonant harmony in Jeong-yun's speech is analyzed and to account for the phenomena, we adopt the four constraints introduced in (1).

(1) a. ID-pos (velar): Velars in particular position should retain the featural specification in the output.
b. Align-L (velar): Align Velars left.
c. IDENT (place): Articulator features in the input should retain identity in the output.
d. DEP: All segments in the output should have correspondent elements in the output.

(2) 포크 → 코크 [$k^ho.k^hi$] (Jeong-yun, 27 months)

ID-pos(velar) >> Align-L(velar) >> IDENT(place)[1] >> DEP

Input : /fɔ:k/	ID-pos(velar)	Align-L(velar)	IDENT(place)	DEP
☛ a. $k^ho.k^hi$			*	*
b. $p^ho.k^hi$		*!		*
c. $k^ho.p^hi$	*!			*
d. $p^ho.p^hi$	*!	N/A	*	*

Because there exists consonant harmony that triggers labials to become velars, ID-pos(velar) must outrank and Align-L(velar) constraint outrank IDENT(place) constraint which accounts for the consonant harmony. The first candidate [$k^ho.k^hi$][2] is optimal with the constraint hierarchy.

Next we will see the process from consonant harmony to metathesis, through this phenomena, constraint (1) could be accounted the process properly.

(3) 포크 → 코프 [$k^ho.p^hi$](Jeong-yun, 32 months)

Align-L(velar), IDENT(place) >> ID-pos(velar)[3] >> DEP[4]

Input : /fɔ:k/	Align-L(velar)	IDENT(place)	ID-pos(velar)	DEP
☛ a. $p^ho.k^hi$	*!			*
b. $k^ho.k^hi$		*!		*
c. $p^ho.p^hi$	N/A	*!	*	*
d. $k^ho.p^hi$			*	*

To gain the optimal form, it needs to demote ID-pos(velar), after promoting Align-L(velar) eliminates (3a), and (3b) and (3c) are eliminated on fatal violations of IDENT(place). When IDENT(place) is outranked, the

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[1] In principle, faithfulness constraints unspecified for a feature in the consonant harmony analysis must be ranked lower than IDENT(labial) instead of IDENT (place), however now IDENT(place) is positioned in order to show the process of promotion of faithfulness constraint. Metathesis is shown next chapter with using IDENT(labial).

[2] Labio-dental, /f/ is shown in the input as the underlying form, and candidate is shown as labial, [p] however, two of them have labial feature, so considered IDENT(place) by satisfying (3b, 3c, 3d).

[3] It is proposed the movement down to show it.

[4] It is shown vowel insertion.

second candidate [$k^ho.k^hi$] is eliminated and triggers consonant harmony. [$k^ho.p^hi$] is optimal. We could explain the hierarchy of the process from consonant harmony to metathesis.

(4) 포크 → 포크 [$p^ho.k^hi$] IDENT(place) >> Align-L(labial) >> DEP

Input : /fɔ:k/	IDENT(place)	Align-L(labial)	DEP
☛ a. $p^ho.k^hi$			*
b. $k^ho.k^hi$	*!		*
c. $k^ho.p^hi$		*	*

(4) illustrates consonant harmony and similar phenomena with adults' speech.[5] We could rule out (4b) with promotion of IDENT(place) and the third candidate is also [$k^ho.p^hi$] ruled out with Align-L(labial). Finally the first candidate [$p^ho.k^hi$] is optimal candidate without violating constraints.

However, the third candidate [$k^ho.p^hi$] is optimal if we would position IDENT(place) instead of Align-L(labial), it triggers metathesis. Hence we could eliminate the third candidate which violated Align-L(labial), it would be comfortable to get an optimal, the first candidate.

Positioning Align-L(labial) in metathesis of adults' speech has differentiation with metathesis which promotions Align-L(velar). As a result, we could account the process of assimilation in adults' speech with the Align constraint. Next we will see the pronunciation of infants who were educated early in English.

To account for this phenomena, it should be positioned by promotion of constrains below. We assume that the phoneme /f/ exists in the infants' acquisition in inventory through exposure to English.

(5) IDENT(fric) : Fricatives have same features in output.

[5] There is no /f/ phoneme entry in Korean, it is generally used [p] in pronunciation, not [f].

(6) 포크 → 포크[6] [fɔ:rk][7] IDENT(fric), DEP >> Align-L(labial)

Input : /fɔ:rk/	IDENT(fric)	DEP	Align-L(labial)
a. phokh	*!	*	
b. khokh	*!	*	N/A
☞ c. fɔ:rk			
d. khoph	*!	*	*

Suboptimal candidates (6a-c) all lose on fatal violations of high-ranking IDENT(fric), (6c) is selected as optimal.

A problem arises if we use IDENT(place) which is a more general faithfulness constraint than IDENT(fricative), IDENT(place) would eliminate (6a) and (6d). We could not eliminate the fourth candidate which is not proper, therefore the third candidate[f:rk] is optimal which has no vowel insertion with the promotion of DEP, is selected as optimal. Above the tableau, faithfulness constraints all are low-ranked and Align is ranked below when there has no consonant harmony or metathesis.

Following the tableau, we could explain the promotion of the faithfulness constraint that governs the retention of features during the process of substitution in Korean infants and similarly in adults' speech. A faithfulness constraint governing the place articulation should be ranked low, as showing plosive feature in output and changing velars into labials. Furthermore, Markedness constraint below should be needed.

(7) *[σ (velar) : No velars in syllable initial position.

Next we analyze assimilation in Ji-yun' s speech. We present the constraints below in (8).

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[6] It is written by 포크, because there is no /f/ in pronunciation in Korean. Jeong-yun already had information of English education on the assumption that the phoneme /p/ is in infants information. Even though there is no /f/ in phoneme entry in Korean, it can be inserted by the environment of the language.

[7] It can be the optimal candidate as well as a candidate in this tableau, because phoneme /f/ is inserted through English education.

(8) a. S + y: S should allow the following velar feature.[8]

b. SHARE(place): Syllable coda should equal place articulation of syllable initial following[9].

(9) 풍선 → 푼션 [p^{h}un.syən] (Ji-yun, 32 months)[10]

SHARE(place) >> S + y >> DEP >> IDENT(place)

Input : /p^{h}uŋsən/	SHARE(place)	S + y	DEP	IDENT(place)
☛ a. p^{h}un.syən			*	*
b. p^{h}uŋ.sən	*!	*		
c. p^{h}uŋ.syən	*!		*	

Alveo-palatals in the syllable coda undergo assimilation. They are apparently influenced by the following syllable onset, in that they should match in their place of articulation. Consequently, (9b) and (9c), which violate SHARE(place) are eliminated. (9a), which illustrates place assimilation, is optimal even though it violates IDENT(place) and S+y. As the acquisition process proceeds, vowel lengthening without assimilation in adults' speech is evident.

(10) 풍선 → 풍션 [p^{h}uŋ.syən] (Ji-yun, 38 months)

IDENT(place) >> S + y >> SHARE(place) >> DEP

Input : /p^{h}uŋsən/	IDENT(place)	S + y	SHARE(place)	DEP
☛ a. p^{h}uŋ.syən			*	*
b. p^{h}un.syən	*!			*
c. p^{h}uŋ.syən		*!	*	

[8] This phenomenon is often appeared in infants speech, it is called palatalization.

[9] In adults speech, when a coronal is in coda position, place assimilation can be accepted, but when a labial or a velar in coda position, place assimilation cannot be accepted positively. However, in infants speech, when a coronal is in coda position, place assimilation can be appeared and affected positively, hence there is a big difference between infants and adults speech.

[10] Assimilation in infants speech is included in substitution phenomena. In adults speech, when a coronal is in coda position, place assimilation can be accepted, but when a labial or a velar in coda position, place assimilation cannot be accepted positively. However, in infants speech, when a coronal is in coda position, place assimilation can be appeared and affected positively, hence there is a big difference between infants and adults speech.

The tableau in (10) shows that there is no assimilation when Ji-yun is 38 months, but vowel lengthening is evident. The place of the second syllable onset and the place of the initial syllable onset should match in place of articulation. SHARE(place) does not play an active role in the evaluation and IDENT(place) is ranked low. Vowel lengthening is evident and IDENT(place) should be followed S+y constraint.

Thus far we have seen the promotion of faithfulness constraints during the acquisition process, and next we consider the analysis of fricative deletion.

2.2 Fricative deletion in Korean

(11) ㅎ → Ø (/h/→ Ø)

/inhɛŋ/ 은행 → 으냉 [inɛŋ] /inhyəŋ/ 인형 → 이녕 [inyəŋ]
/cənhwa/ 전화 → 저나 [cəna] /cənhwaki/ 전화기 → 돈아기 [tonagi]
/sihəmci/ 시험지 → 치엄지 [chiəmci] /ühəm/ 위험 → 위엄 [üəm]
/manhwa/ 만화 → 망와 [maŋwa] /hyuci/ 휴지 → 유지 [yuci]

Korean infants disallow /h/ in intervocalic position. This is remedied through deletion. The constraint adopted to account for this deletion presented in (12).

(12) *VhV: : No /h/ in intervocalic position

(13) 위험 → 위엄 [ü.əm](Sang-jun, 45 months) *VhV >> MAX

Input : /ühəm/	*VhV	MAX
☛ a. ü.əm		*
b. ü.həm	*!	

/h/-deletion in intervocalic position indicates that *VhV must be high-ranked. Hence, (13a) is optimal even though it violates MAX, (13b) loses on a fatal violation of high-ranked *VhV. As we have seen so far, it is appropriate to account for deletion in Korean infants in a similar fashion as with the grammar of adults.

2.3 Substitution in Korean fricatives

(14) a. ㅎ→ ㅋ (/h/ → [k^h])
/hakwən/학원 → 카권 [k^hagwən] /hopak/ 호박 → 코박 [k^hobak]
b. ㅎ → ㅅ (/h/ → [s])
/hyosəŋ/ 효성 → 쇼성 [syosəŋ] /hyuci/ 휴지 → 슈지 [syuci]
/him/ 힘 → 심 [sim]
c. ㅎ → ㅍ (/h/ → [p^h])
/hwap^{h}yəŋ/ 화평 → 파평 [p^hap^{h}yəŋ]

Substitution of /h/ by [k^h], [s], and [p^h] is the repair in Korean while /h/-deletion is generally evident in English. Next we will analyze the substitution fricative /h/ by [s] in Korean.

(15) 휴지 → 슈지 [syu.ci](Ji-yun, 38 months)
*[σ (glottal) >> S + y, MAX >> IDENT(glottal)

Input : /hyuci/	*[σ (glottal)	S + y	MAX	IDENT(glottal)
☞ a. syu.ci				*
b. hyu.ci	*!	*		
c. hu.ci	*!	*	*	

It is important to account infants' language acquisition, especially fricative acquisition by promoting *[σ (glottal). (15b) and (15c) are eliminated by fatally violating *[σ (glottal).

Next we analyze the plosiveness of fricatives. To explain this phenomena, we need a markedness constraint in avoidance with the same pattern applying language acquisition of infants. Next, we will analyze the substitution fricative /h/ by [kh] is analyzed.

(16) 호박 → 코박 [k^ho.bak](Sang-jun, 45 months)
*[σ (fric) >> IDENT(place), IDENT(manner)

Input : /hopak/	* [σ (fric)	IDENT(place)	IDENT(manner)
a. ho.bak	*!		
☞ b. kho.bak		*	*

It is possible to account the changing of the fricative /h/ to /k^h/ by ranking *[σ (fric) high and ranking the faithfulness constraint low. However, as shown (16), (16b) and (16c) are eliminated on violations of IDENT, they are optimal candidates if the third candidate is positioned which has consonant harmony. Hence to obtain the optimal candidate in order to account this problem, IDENT should be outranked which eliminates the third candidate.

(17) 호박[11] → 코박 [kho.bak](Sang-jun, 45 months)

*[σ (fric) >> IDENT(place), IDENT(manner)

Input: /hobak/	*[σ (fric)	IDENT(place)	IDENT(manner)
a. ho.bak	*!		
☞ b. kho.bak		*	*
☞ c. pho.bak		*	*

The third candidate which has a glottal feature in input has consonant harmony influenced by labials, glottals could not be correspondents of consonant harmony. We need the constraint introduced below.

(18) *CH(glottal): Glottals can not be correspondence of consonant harmony.[12]

With the above constraint, glottal /h/ can be a correspondent of consonant harmony and change into a labial. Thus, the second candidate is optimal. It should reanalyze the validity in general language and need to consider the consonant harmony of glottals in infants' speech.

Next we will analyze the substitution of Korean affricates. This is the opposite of the phenomena which substituted an alveo-palatal for an alveolar.

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[11] /hopak/ is the input form without vocalization of /p/, as (24) shown, /hobak/ is the exact input form with vocalization of /p/. In optimality theory, any input form cannot affect the selection of optimal candidate.

[12] It can be accounted to rank down *CH(glottal), therefore it is also appeared consonant harmony, 화평 /hwap^{h}yəŋ/ → 파평 [p^{h}ap^{h}yəŋ].

2.4 Substitution of Korean affricates

It is observed that plosiveness can be seen as the change of affricates to plosives as well as to fricatives in Korean. As we have seen so far, consonant harmony appeared simultaneously when the two affricates changed to plosives. To account for this phenomenon, a markedness constraint must be high-ranked, because segments in the input changed their place articulation and manner in the output, obviously violating IDENT(manner) and IDENT(place). This markedness constraint is presented in (28).

(19) *[σ (affricate) : Affricate feature cannot be in syllable initial.

(20) 자동차 → 다동타 [ta.doŋ.t^{h}a][13] (Jung-yun, 27 months)

*[σ (affricate) >> IDENT(manner), IDENT(place)

Input: /cadoŋc^{h}a/	* [σ (affricate)	IDENT(manner)	IDENT(place)
a. ca.doŋ.c^{h}a	*!		
b. ta.doŋ.t^{h}a		**!	**
☞c. ta.doŋ.c^{h}a		*	*

However, subopitmal (20c)[14] is selected as optimal according to this ranking is (20b)[15] the optimal candidate. This requires the constraint illustrated in (21). Moreover, it should be ranked constraint (21) to attain to get a optimal candidate.

(21) *σ](affricate) : Affricate feature cannot be in syllable coda.

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[13] Dentalization in Korean affricates is generally included in dentalization of palatals, that is fronting of palatals.

[14] ☞ is the wrong output form.

[15] /c/ is changed to [j] and /t/ to [d] in vocalization between vowels.

(22) 자동차 → 다동타 [ta.doŋ.t^{h}a] (Jung-yun, 27 months)

*[σ (affricate), * σ](affricate) >> IDENT(manner), IDENT(place)

Input: /cadoŋc^{h}a/	*[σ (affricate)	* σ](affricate)	IDENT(manner)	IDENT(place)
a. ca.doŋ.c^{h}a	*!	*		
☛ b. ta.doŋ.t^{h}a			**	**
c. ta.doŋ.c^{h}a		*!	*	*

As identifying tableau, the third candidate is ruled out by * σ](affricate), and the second candidate [ta.doŋ.t^{h}a] is optimal even though it violates a faithfulness constraint governing place articulation and manner, because it does not preserve the features of affricates and alveo-palatals in the output.

In this case, it should be outranked *[σ (affricate) and * σ](affricate) when the processes of feature substitution and consonant harmony occur simultaneously.[16]

Next, we consider the fronting of palatalization. It can be the fricativeness of affricates, as in the preceding example, IDENT should be ranked below with violating place articulation and manner of faithfulness constraints.

(23) 창문 → 샹문 [syaŋ.mun][17] (Young-roh, 44 months)

*[σ (affricate) >> S + y >> IDENT(manner) >> IDENT(place)

Input: /c^{h}aŋmun/	*[σ (affricate)	S + y	IDENT(manner)	IDENT(place)
a. c^{h}aŋ.mun	*!	*		
☛ b. syaŋ.mun			*	*
c. taŋ.mun	*!	*	*	*

The second candidate [syaŋ.mun] violates IDENT, but aligns the fricative

[16] There are two substitution phenomena when two dental palatals in input were changed to dentals in output, even though consonant harmony seemed to appeared in result. Hence there cannot be used positional faithfulness constraint in consonant harmony, also needs more complex constraints.

[17] In this thesis, the phenomena that dental palatals were changed to dentals violates the faithfulness constraint of place articulation, even though dentals can keep their features and the faithfulness constraint.

left and satisfies *[σ (affricate). Therefore it is optimal candidate. The first candidate [c^{h}aŋ.mun] is ruled out by violating *[σ (affricate) fatally, and the third candidate violates all the constraints in the tableau in (23). Fricativeness of affricates in Korean is explained by ranking *[σ (affricate) high and faithfulness constraint low.

It has been argued that the phonological phenomena of fricatives in Korean and analysis on fricatives and affricates in Korean so far. In several substitutions as plosiveness of fricatives in English, IDENT is ranked low, and the markedness constraint is high-ranked when the target of substitution is avoided. Next we will analyze the liquids in Korean.

2.5 Phonological phenomena in Korean liquids

Nasalization of liquids in Korean are more familiar in syllable initial position and deletion is the repair process when liquids are in intervocalic position. We will explore the difference below.

(24) ㄹ → ㄴ (/l/ → [n])
/talkyal/ 달걀 → 달갼 [talgyan] /latio/ 라디오 → 나디오[nadio]
/lamyən/ 라면 → 나면[namyən]
/limouk^{h}on/ 리모콘 → 니모콘 [nimok^{h}on]
/milkalu/ 밀가루 → 밀까누[milk'anu]

(25) ㄹ → ㄷ (/l/→/r/→[d])
/noli/ 놀이 → 노디[nodi]

(26) ㄹ→ /y/, Ø (/l/→/r/ →/y/ or /l/→Ø or /l/→/r/→Ø)
a. /l/→/r/→/y/
/palam/ 바람 → 바얌[payam] /kyelan/ 계란 → 계얀[kyeyan]
b. /l/→Ø
/kwail/ 과일 → 가위[kaü] /milkh/ 밀크 → 미크[mik^h]
c. /l/→/r/→Ø
/moktoli/ 목도리 → 목또이[mokt'oi]
/hanmali/ 한마리 → 한마이[hanmai]

Thus far, we have yet to analyze syllable initial liquids. Liquids are assimilated to nasals in syllable initial in Korean. Liquids are not allowed in syllable initial position, thus *[σ (liquid) must be high-ranked in Korean. IDENT(place) should not be needed to position, since it has same feature of place articulation which is followed alveolar in input to output.

(27) 라디오 → 나디오 [na.dio](Hyeon-ji, 31 months)

*[σ (liquid) >> IDENT(manner)

Input:/radio/	*[σ(liquid)	IDENT(manner)
☞ a. na.dio		*
b. ra.dio	*!	

As shown in (27), this phenomenon is accounted for by ranking *[σ (liquid) high in Korean. Optimal (27a), which shows manner assimilation, wins on satisfaction of high ranked *[σ (liquid) despite a violation of low-ranked IDENT(manner).

Next, we consider deletion of liquids. To explain this phenomenon, we formulate the markedness constraints introduced below in (28).

(28) a. *VrV : No liquid /r/ in intervocalic place.
*VV : No hiatus.

(29) 한 마리 → 한마이 [han.ma.i][18] (Ju-hyeong, 27 months)

*VrV >> *VV >> MAX

Input : /hanmari/	*VrV	*VV	MAX
a. han.ma.ri	*!		
☞ b. han.ma.i		*	*

Suboptimal (29a) is eliminated on a fatal violation of *VrV fatally, whereas (29b) is optimal despite minimal violations of *VV and MAX. The following tableau presents an additional analysis of /r/-deletion in

[18] Liquid deletion between vowels(or voiced) is shown the difference between the liquid /r/ substitution between vowels in onset and liquid deletion, is deleted oftenly in Korean, as knowing liquids is a phoneme with [-lateral] feature, that is [+continuant] feature.

intervocalic position.

(30) 계란 → 계얀 [kye.yan](Jeong-yun, 27 months) *VrV >> *VV

Input : /kyeran/	*VrV	*VV	IDENT(manner)
a. kye.ran	*!		
☞ b. kye.yan			*

*VrV must be high-ranked to eliminate /r/ from surfacing in intervocalic position in infants' speech. This is evident in input-faithful (30a) which violates the high-ranked *VV. The optimal candidate (30b) satisfies *VV through /y/ insertion. Next we consider an analysis of the substitution and deletion of liquids.

(31) 놀이 → 노디 [no.di][19] (Young-roh, 44 months)

*VrV[20] >> IDENT(manner)

Input:/nori/	*VrV	IDENT(manner)
☞ a. no.di		*
b. no.ri	*!	

As shown in (31), the liquid /r/ is substituted by a plosive when it occurs in intervocalic position. As in the cases of deletion, *VrV must be high-ranked to motivate substitution. On the other hand, IDENT (manner) must be low-ranked down to permit this substitution.

To summarize the analysis of Korean liquids presented here, it has been observed that nasalization in syllable initial and deletion in intervocalic position are the repair strategies that Korean utilizes in order to avoid /r/ from surfacing in illicit positions. In the case of liquid nasalization it was argued that - *[σ (liquid) ? must crucially dominate- >>IDENT(manner) and in the case of deletion in intervocalic position,- it was evident that the ranking was *VrV >> *VV. Next we will see the phonological phenomena of syllable structure.

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[19] Resyllabification is appeared and substitution when a consonant is deleted in coda position and moved to onset position.

[20] Acquisiton of melodic level and syllable structure, that is prosodic level was discussed and shown in Archibald (1995:46-50).

2.6 Substitution and phonological phenomena of syllable structure

We will analyze substitution and phonological phenomena related to syllable structure simultaneously. First, a similarity arises when substitution and deletion apply together. The following constraint is necessary to eliminate velars from surfacing in coda position.

(32) *σ](velar) : No velars in syllable coda.

(33) 장갑 → 잠바 [cam.ba][21] (Ji-yun, 38 months)

*[σ(velar), *σ](velar) >> IDENT(place) >> MAX

Input : /caŋgap/	*[σ(velar)	*σ](velar)	IDENT(place)	MAX
a. caŋ.ga	*!	*		*
☞ b. cam.ba			**	*

Optimal (33b) wins on satisfaction of high ranking *[σ(velar) and *σ](velar), while suboptimal input-faithful (33a) violates both.

Next we will analyze /h/ deletion and the substitution of affricates by plosives simultaneously.

(34) 전화기 → 돈아기 [ton.a.gi][22] (A-roh, 44 months)

*[σ(affricate), *VhV[23] >> IDENT(place), IDENT(manner) >> MAX

Input : /cənhwaki/	*[σ(affricate)	*VhV	IDENT(place)	IDENT(manner)	MAX
☞ a. ton.a.gi			*	*	*
b. cən.hwa.gi	*!	*			
c. cən.a.gi	*!				*
d. ən.ha.gi		*!	*	*	*

[21] This rare phenomenon is often observed in infants speech. There is not exact explanation that a velar is substituted a labial and the velar has assimilation of place articulation to the labial.

[22] Substitution of vowels is ignored in this thesis, also not ranked IDENT (voice).

[23] There cannot be /h/ between vowels or sonorants, that is between voiced phonemes.

Candidates (34b) and (34c) both lose on violations of high-ranking *[σ (affricate), while (34d) loses on a fatal violation of *VhV.

As we have seen so far, when deletion and substitution take place simultaneously, IDENT and MAX must be low-ranked. *[σ (affricate) which prohibits affricates in the syllable onset and *VhV which prohibits /h/ intervocalicly must be high-ranked. Thus, the candidate that undergoes substitution and deletion is optimal.

So far, we have analyzed the phonological acquisition of substitution in Korean as well as phonological phenomena related to the role of syllable structure. In infants' speech, multiple and complex phonological phenomena would be made pronunciation of infants comfortable and faithfulness constraint should be dominated by markedness constraint with avoiding certain patterns of pronunciation. This is accountable within Optimality Theory. In the next section, we will consider consonant harmony and metathesis, two robust phenomena in infants' speech.

3. Consonant harmony and metathesis

Consonant Harmony, evident here, is essentially the velarization or the labialization of coronals. When a coronal is velarized or labialized by a following segment, this is termed regressive harmony, whereas when a coronal is labialised or velarized by a preceding segment, this is termed progressive harmony. In exceptional cases, there were instances where a labial assimilated to a velar or coronal in Korean infants. Among several kinds of metathesis, for example, metathesis between consonants and metathesis between consonants and vowels. Here we will see metathesis between syllables in Korean infants.

3.1 Consonant Harmony Data

/kapaŋ/ 가방 → 바방 [pabaŋ] /koŋpu/ 공부 → 공구 [koŋgu]
/tupu/ 두부 → 두두 [tudu] /papkaps/ 밥값 → 가깝 [kak'ap]
/polp^{h}en/ 볼펜 → 폴펜 [p^{h}olp^{h}en] /sat^{h}aŋ/ 사탕 → 타탕 [t^{h}at^{h}aŋ]
/samc^{h}on/ 삼촌 → 삼춤[24] [samc^{h}om]/samc^{h}on/ 삼촌 → 탐톤 [t^{h}amt^{h}on]

[24] It is shown consonant harmony in syllable coda, /samchon/ 삼촌, 삼춤

/uc^{h}et^{h}oŋ/ 우체통 → 우태통 [ut^{h}et^{h}oŋ] /kəpi/ 커피 → 퍼피 [p^{h}əp^{h}i]
/fɔ:rk/ 포크 → 코크 [k^{h}ok^{h}i]

(35) Labial velarization (labial → velar)

a. Regressive velar movement
/papkaps/ → [kak'ap]
/fɔ:rk/ → [k^{h}ok^{h}i]

b. Progressive velar movement
/koŋpu/ → [koŋgu]

(36) Labial coronalization (labial → coronal)
Progressive coronal harmony
/tupu/ → [tudu]

(37) Velar labialization
Regressive labial harmony
/kəpi/ → [p^{h}əp^{h}i]

The example in (35) presents labial velarization. This process, which is absent in English, is quite evident in Korean adults' speech. Example (36) presents progressive labial coronalization and (37) represents velar labialization. Examples above do not occur in Korean adults' speech.

3.2 Analysis on consonant harmony[25] and metathesis

We will analyze the consonant harmony cases, namely velar labialization in Korean infants in optimality theory, which were not accounted for in rule-based theory.[26]

[samchom] in infants speech well.

[25] This constraint is from Velleman. (1996)

[26] This phenomena that a velar to a labial is also appeared in American infants.

(38) 커피 → 퍼피 [pə.pi][27] (Jeong-yun, 27 months)

ID-pos(labial) >> Align-L(labial) >> IDENT(velar)

Input : /kəpi/	ID-pos(labial)	Align-L(labial)	IDENT(velar)
a. kə.pi		*!	
☞ b. pə.pi			*
c. kə.ki	*!	N/A	

Suboptimal (38c) is eliminated by violating the positional faithfulness constraint, while (38a) is eliminated by Align-L(labial). Thus, (38b) is optimal on the satisfaction of high-ranked constraints. Therefore, velar labialization, which was unable to be accounted for in a rule-based analysis, is sufficiently accounted for using OT, and more specifically Positional Faithfulness. Furthermore, the coronal underspecification principle was unable to explain this phenomena that is easily accounted for in an optimality theoretic framework. To summarize thus far, various consonant harmony patterns, which were problematic for rule-based theory, in infants is accounted for using optimality theory. Next we will consider patterns of metathesis.

(39) a. Labial-Left: Labials should be aligned left.[28]
b. Velar-Right: Velars should be aligned right.

(40) 가방 → 방가[paŋ.ga](Ji-yun, 32 months)

IDENT(place), Labial-Left, Velar-Right >> LINEARITY

Input : /gapaŋ/	IDENT(place)	Labial-Left	Velar-Right	LINEARITY
☞a. paŋ.ga			*	*
b. pa.baŋ	*!	*		
c. ga.baŋ		*!	*	

[27] Velars must underspecify in this data when original consonants in underspecification principle have to underspecify, hence consonant harmony in Korean infants speech cannot be accountable in principle.

[28] The left side in the middle of the center is included the edge of the left. In other words, Labial-Left constraint includes Align-Left(labial). In this analysis, the changed segment [b] is positioned at the edge of the word, therefore Align-Left(labial) instead of Labial-Left is also can be optimal constraint.

The second candidate [pa.baŋ][29] and the third candidate [ga.baŋ][30] are ruled out by violating two outranked constraints and the last first candidate [paŋ.ga] is optimal one with violating by one outranked constraint. As we seen in (40), the metathesis between consonants is outranked by IDENT, Labial-Left and Velar-Right and LINEARITY is ranked down.

Hence, in the metathesis analysis, IDENT, ALIGN or a constraint which states that a certain segment should be in the right or left must be high-ranked. We have observed the preservation of consonantal properties and aspects of variation in metathesis and consonant harmony thus far. When positional faithfulness constraints, which infants' preferred features, is high-ranked and positional faithfulness constraint, which infants' non-preferred feature is low-ranked, there exists consonant harmony. Finally metathesis is selected through ranked faithfulness constraint, which retain feature values, high and ranked positional faithfulness constraint low.

4. Conclusion

This paper gave an optimality theoretic account of liquids, fricatives, affricates and consonant harmony and metathesis patterns evident in the speech of Korean infants. Optimality Theory had advantages in handling these phonological phenomena over the traditional rule-based theories.

In substitution process, feature in input could not keep its feature and other feature changed. Therefore, faithfulness constraints of features, that is, IDENT constraints, must be ranked low. In this paper, we have concluded that IDENT(manner) had more violations than IDENT(place) among IDENT constraints in infants' substitution process. Hence, we captured the fact that infants generally inclined to keep feature of place articulation than manner articulation.

As infants' growth, there appeared the phenomena that faithfulness constraint gradually ranked higher in acquisition of consonants. In other

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[29] If this candidate with consonant harmony is optimal one, ID-pos(labial) must be ranked high.

[30] The labial /b/ is not positioned in left side in the middle of the center, hence this candidate violates Labial-Left.

words, when infants learn languages at first, faithfulness constraint ranked down and finally ranked higher during acquisition of consonants.

In infants' speech, strong markedness constraints such as *[σ (affricate), *VrV which were not used in adults' speech were used to account for various phonological phenomena. Thus, that the constraints in OT are language universal can be problematic.

In adults' speech, when a coronal is in coda position, place assimilation can be accepted, but when a labial or a velar in coda position, place assimilation cannot be accepted positively. However, in infants' speech, when a coronal, a labial, a velar are in coda position, place assimilation can be appeared and affected positively, there is a big difference between infants' and adults' speech.

Hence the constraint such as SHARE(place) are more powerful in infants' speech than in adults' speech.

The utterances of infants show various consonant harmony patterns such as labial-velar harmony, velar-labial harmony and labial-coronal harmony. When the target is glottal which is triggered by labial, consonant harmony may appear, or may not appear. These differences were also analyzed within the framework of Optimality Theory.

There are several kinds of metathesis, such as metathesis between consonants, metathesis between consonant and vowel, metathesis between syllables. Among these, in this paper, we also analyzed the metathesis between syllables.

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