

Dynamic and static aspects of laryngeal co-occurrence restrictions in Korean^{*}

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Kang, Hijo and Mira Oh. 2016. Dynamic and static aspects of laryngeal co-occurrence restrictions in Korean. *Studies in Phonetics, Phonology and Morphology* 22.1. 3-34. This study investigates the dynamic aspects of laryngeal co-occurrence restrictions whose static aspects have been evaluated. By examining word-initial tensification and adverbializer allomorphy in Korean, we show that a laryngeally marked feature tends to co-occur with the same features in word formations. A tense consonant in the second syllable facilitates the tensification of the word-initial consonant, and an aspirated consonant in an adjectival stem requires *-hi* as an adverbializer rather than *-i*. The analysis of the entire lexicon shows that these patterns are correlated with those in the lexicon. Based on these results, we argue that Korean has an assimilation type restriction (Gallagher 2010), contrary to Ito (2014). This study provides insight about how the dynamic and static aspects of the restrictions interact to form specific patterns in the lexicon. (Chosun University and Chonnam National University)

Keywords: Laryngeal co-occurrence restriction, word-initial tensification, allomorphy

1. Introduction

This study aims to investigate the laryngeal co-occurrence restriction (LCR) that occurs in word-initial tensification and adverb formation in the Korean language. Both phonological and morphological processes indicate that the LCR plays a role in

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that the rate of word-initial tensification is conditioned by the laryngeal specification of the following onset and that the selection of the adverbial suffix allomorph, ‘-hi’, is also restrained by laryngeal specification of the preceding consonant. This study also examines the LCR in the Korean lexicon. By doing so, this study shows that the LCR exerts an influence on the lexicon as a static constraint and it further affects phonological and morphological processes dynamically.

Many languages exhibit some restrictions on the distribution of laryngeal features in their lexicons (MacEachern 1999, Hansson 2001, Rose and King 2007, Gallagher and Coon 2009, Gallagher 2010). Gallagher (2010) presents three patterns of laryngeal restrictions as in (1).

(1) Three types of long-distance laryngeal restrictions (Gallagher 2010): T and K stand for obstruents with different places of articulation and ’ laryngeally marked feature.

a. Dissimilation type (Shuswap, Souletin Basque)

*T’-K’	T’-K	T-K
*T’-T’	T’-T	T-T

b. Assimilation type (Zulu, Kalabari Ijo)

T’-K’	*T’-K	T-K
T’-T’	*T’-T	T-T

c. Mixed type (Chol, Peruvian Aymara)

*T’-K’	T’-K	T-K
T’-T’	*T’-T	T-T

In dissimilation type languages (1a), an obstruent must be maximally specified once for a laryngeal feature (e.g., ejective or aspirated) in a root. In contrast, every obstruent must be specified for the same laryngeal feature in a root in assimilation type languages (1b). In mixed type languages (1c), multiple appearances of the laryngeal feature are allowed only when the consonants share the same place of articulation.

The OCP (Obligatory Contour Principle, Leben 1973) stating that a value for X may appear only once in a domain of Y (McCarthy 1986: 218) retains the same phonological features as laryngeal features and include features that occur in a root or

a word (McCarthy 1986, 1989, Mester 1986, Yip 1989, Padgett 1995, Davis 1991, H. Kang 2013, etc.)¹. The OCP effect may play a role in phonological alternation, though only a few cases have been reported. In Ofo, for instance, the OCP constraint that prohibits aspirated consonants from appearing more than once in a root triggers alternations in the domain of a word, e.g., /osk^ha+af^ha/ → [oskaf^ha] ‘the white or American egret’ (MacEachern 1999).

The long-distance laryngeal co-occurrence restrictions stated in (1) can be understood as an extended OCP in that both phonological similarity and dissimilarity between segments are calculated. All of the examples used by Gallagher (2010) are static in the sense that they are all based on the segmental patterns in the lexicon for each language. This is very specific to the LCR constraints in Gallagher’s study in that many other constraints exert their influence on dynamic procedures. Then a question arises as to whether the long-distance laryngeal co-occurrence restrictions are also evident in phonological alternation or morphological processes.

To investigate the question, we analyze the LCR that occurs in word-initial tensification and adverb formation in Korean. By doing so, we aim to answer the following questions in (2).

(2) Research Questions

- a. What type of LCR is found in dynamic procedures in Korean?
- b. If the LCR influences phonological and morphological processes, is it a reflection of lexical statistics in the language?
- c. How does the restriction interact with the three-way contrast of laryngeal features in Korean obstruents?

This study is structured as follows. In section 2, two phenomena in Korean, which are the main interests of this paper, are presented, followed by the predictions made based on previous research. Section 3 reports a judgment experiment on word-initial tensification and lexical analysis of adverbialization. The results are compared with that of the analysis of the entire Korean lexicon. Section 4 discusses the findings of this study in light of the research questions we set. Section 5 concludes the paper.

¹ While the laryngeal co-occurrence restrictions are, by and large, categorical, the place co-occurrence restrictions are gradient (Frisch et al. 2004).

2. Word-initial tensification and adverbialization allomorphy

2.1 Three-way laryngeal contrast in Korean obstruents

Korean stops and affricates exhibit a three-way contrast in terms of laryngeal features: lax, tense, and aspirated. However, alveolar fricatives have a two-way contrast. Table 1 shows the pattern.

Table 1. Phonemic obstruents in Korean

	place	lax	tense	aspirated
stop	labial	p	p'	p ^h
	coronal	t	t'	t ^h
	dorsal	k	k'	k ^h
affricate	coronal	tc	tc'	tc ^h
fricative	coronal ²	s	s'	
	glottal			h

Korean oral stops, in particular, are all phonemically voiceless and distinguished by VOT and F0 (J. Han 1996, T. Cho et al. 2002, H. Choi 2002, M. Kim 2004 among others). VOTs saliently differentiate tense (the shortest) from lax (intermediate) and aspirated (the longest) and F0 lax (low) from tense and aspirated (high). These acoustic differences are considered to result from different glottal configurations (Kagaya 1974), thyroarytenoid muscle activity (Hirose et al. 1974) and linguopalatal contact (T. Cho and Keating 2001). Considering that the LCR constraints only apply to marked features (ejective and aspirated in Gallagher 2010), it is expected that the constraints, if any, will apply to the laryngeally marked features in Korean, too. Following Cho (2011) and many others, tense and aspirated consonants are regarded as marked in this study. We will pay attention to the Korean tense obstruents, which are typologically rare. In other words, we will see whether the tense obstruents

² There is no consensus on the laryngeal status of coronal fricatives. While it is agreed that /s'/ is categorized as tense, /s/ is claimed to be lax or aspirated. Phonologically, it behaves as lax in post-obstruent tensing (S. H. Kim 2003) and even in intervocalic voicing (T. Cho et al. 2002). Phonetically, /s/ shows the characteristics of both lax and aspirated stops. It is similar to aspirated stops in having aspiration in word-initial positions but to lax stops in lowering F0 and raising the H1-H2 of the following vowel (T. Cho et al. 2002).

behave similarly to other marked obstruents in other languages with regard to LCR.

2.2 Word-initial tensification

Lax consonants are realized as tense via various phonological and/or morphological processes in Korean. To begin with, a lax consonant becomes tense after an obstruent (post-obstruent tensification, e.g., *ip-to* [ip[˥]t'o] ‘mouth-also’, S. Lee 1999). While this is an automatic phonological process, tensification can also be morphologically conditioned. For example, a suffix-initial lax consonant becomes tense after a verbal-stem-final nasal (post-nasal tensification, e.g., *sin-ko* [sink'o] ‘to wear-and’ vs. *sin-to* [sindo] *[sint'o] ‘shoes also’)³. Another tensification results from overapplication of post-obstruent tensification after consonant cluster simplification (post-cluster tensification, e.g., *malk-ta* [malt'a] ‘to be clear-Indicative’)⁴. Another case of tensification occurs across a word boundary. When two nouns form a compound, the so-called ‘sai-sios’ is placed between them and triggers tensification (compound tensification, e.g., *san-pul* [sanp'ul] ‘mountain-fire’, Sohn 1999). Compound tensification has been analyzed semantically (C. Kim 1996, Yun 2006), syntactically (Oh 1988), morphologically (Ahn 1985), and phonologically (Zuraw 2011, Ito 2014). However, none of these factors can successfully predict where and how frequently compound tensification takes place. Likewise, tensification in Korean results from various reasons and factors.

Word-initial tensification is one of the main concerns of this paper. Unlike other tensification processes mentioned above which occur in the middle of a word except for compound tensification, word-initial tensification is a process by which a lax obstruent is realized as tense in the word-initial position. It also differs from other tensification processes in optionality as given in (3).

³ In general, a lax stop becomes voiced between sonorants in Korean.

⁴ Tensification in */malk-ta/* [malt'a] ‘to be clear-Indicative’ is not surface-true since the stem-final /l/ does not trigger tensification as in */mal-ta/* [malda] *[malt'a] ‘to wind up-Indicative’. However, we will not further study how to analyze such counterbleeding ordering of tensification since it is not an issue in this paper.

(3) Word-initial tensification

teak-	[teak] or [te'ak]	'small'
se-	[se] or [s'e]	'strong'
kam-	[kam] or [k'am]	'to shampoo'
pok'-	[pok] or [p'ok]	'to fry'
sonaki	[sonagi] or [s'onagi]	'squall'
twetɛi	[twetɛi] or [t'wetɛi]	'pig'

By tensifying a word-initial lax consonant, Korean speakers intensify the meaning of the word, specifically when the word is an adjective⁵. By analyzing 233 words in consultation with 5 Korean speakers, D. Park (2000) claims that word-initial tensification takes place not only to intensify, but to deteriorate or differentiate the meanings of words. By categorizing the semantic functions of word-initial tensification, he concludes that it is a way of avoiding homonyms in Korean. For instance, *se-* is a homophone, which means 'to count' or 'to be strong'. Of the two morphemes, only the latter undergoes word-initial tensification. Consequently, *se-* and *s'e-* are distinguished in the form, as well as in the meaning. Many researchers have investigated the sociolinguistic aspects of this phenomenon. It has been reported that word-initial tensification is more likely in younger (M. Lee 1989, Y. Kim 2004, M. Han 2011)⁶ and female (Y. Kim 2004) speakers. Other factors such as the origin of the word and the morphological category are known to be involved. Pure Korean words are more prone to word-initial tensification than Sino-Korean words (D. Park 2000, Y. Kim 2004, M. Han 2011, 2013). Verbals are known to have a stronger tendency for word-initial tensification than nominals (H. Kang 2001, M. Han 2011, 2013)⁷. On the other hand, it is hard to find any phonological factors that affect word-initial tensification (D. Park 2000). To our knowledge, the only phonological analysis of word-initial tensification is Wee's (2008) study, where the likelihood of word-initial tensification is found to be in the order of /k>/te>/s>/t>/p/.

This study examines another phonological factor in word-initial tensification,

⁵ For example, [s'e] in (3) would give an impression of 'stronger' compared to its lax counterpart, [se]. This effect is also found in nouns. The word-initial tensification fortifies the main feature of the noun. [t'wetɛi] in (3) would describe a fatter person than [twetɛi] would. However, this effect is not found in verbs.

⁶ The opposite tendency is reported in the Chonnam variety (H. Kang 2001, E. Lee 2011).

⁷ The opposite tendency is reported by Y. Kim (2004).

focusing on the laryngeal co-occurrence restrictions, i.e., the effect of the laryngeal feature of the following onset. Even though the word-initial tensification is lexically determined in general, it can also be affected by phonological factors such as compound tensification (Zuraw 2011, Ito 2014). By conducting a judgment survey (section 3.1), we will show that laryngeal co-occurrence restrictions affect word-initial tensification.

2.3 Adverbializer allomorphy

‘-i’ and ‘-hi’ are allomorphs of the adverbializer suffix. It has been assumed that the allomorphs are selected on the basis of lexical items (the 51th clause in Hangeul Orthography), as presented in (4). Assuming that /h/ belongs to the aspirated obstruents⁸, we will show that the distribution of ‘-i’ and ‘-hi’ is constrained by the laryngeally marked obstruents in stems.

(4) adverbializer ‘-i’ and ‘-hi’

a. k’ek’tus-i	clean-i	cleanly
nalk’halo-i	sharp-i	sharply
b. kuip-hi	hasty-hi	hastily
t’uuk-hi	special-hi	specially
c. solteik-i/hi	frank-i/hi	frankly
k’omk’om-i/hi	careful-i/hi	carefully

The stems in (4a) are combined only with ‘-i’ and those in (4b) only with ‘-hi’. But the stems in (4c) can take either ‘-i’ or ‘-hi’. No previous study of phonological constraints on ‘-i/-hi’ allomorph selection has been reported.

2.4 Laryngeal co-occurrence restrictions in Korean

Ito (2007) analyzed 1,419 monosyllabic roots in the pure Korean lexicon and found a categorical constraint prohibiting two aspirated consonants and a gradient co-occurrence restriction of the place features. Except for coronal sonorant pairs, the identical pairs (labial, dorsal, and coronal obstruent pairs) are underrepresented in the

⁸ Ito (2014) separates /h/ from aspirated obstruents in contrast to our assumption.

lexicon. Furthermore, Ito (2014) claimed that compound tensification is less likely to occur when the words of interest contain tense and/or aspirated consonants in Yanbian Korean after conducting a corpus experiment and two wug tests. Based on the results, she argues that Korean has dissimilation type laryngeal co-occurrence restrictions, by which multiple appearances of marked features (tense and aspirated) are basically avoided. However, she noted that the patterns in Korean simple nouns are not consistent with the results: tense-tense onset pairs are significantly overrepresented, while aspirated-tense pairs are underrepresented without statistical significance in the Korean lexicon. She argues that the tendency in compound tensification results from the emergence of a dissimilation type of laryngeal co-occurrence restriction and that the overrepresentation of tense-tense pairs results from a regressive assimilation of [constricted glottis], which is the main feature of tense consonants.

If Korean has dissimilation type restrictions as Ito argues, a tense consonant and an aspirated consonant will basically prohibit word-initial tensification and the selection of ‘-hi’, respectively. On the contrary, if the restrictions in Korean belong to the assimilation type, opposite patterns will emerge. Moreover, if the overrepresentation of tense-tense pairs in Korean simple nouns results from a regressive assimilation as Ito argues, the word-initial tensification will be facilitated by another tense consonant in the second syllable, even if Korean has dissimilation type restrictions. We will investigate which predictions are borne out by conducting a judgment survey experiment of word-initial tensification and a lexical analysis of the adverbializer allomorphy.

3. Survey experiment

To test the predictions made above, we conducted a judgment survey experiment on the acceptability of word-initial tensification, a lexical analysis of the adverbializer, and analysis of the whole lexicon.

3.1 A judgment survey of word-initial tensification

A judgment survey was conducted to determine Korean speakers’ intuition on word-initial tensification. We carefully selected appropriate stimuli for the experiment. As mentioned in section 2.2, the likelihood of word-initial tensification is primarily

determined by the lexical items. To tease apart this lexical effect and the phonological effect, we excluded words that have already gone through word-initial tensification from the critical stimuli of the survey. Another reason for excluding such words with established tense alternates was that the words that already undergo word-initial tensification are not balanced in terms of the phonological factors for the survey.

We used Korean words that rarely undergo word-initial tensification as the stimuli. The morphological category, type of initial consonant, and type of second onset consonant⁹ were taken into consideration for choosing the stimuli. We chose the four categories in lexical words (noun, verb, adjective, and adverb) to test the morphological effect since there is no consensus on the effect of the morphological category. Every stimulus began with one of the five lax consonants (target: /p/, /t/, /tʰ/, /s/, and /k/) which can be subject to tensification and the second onsets consisted of lax, tense, aspirated, nasal, liquid, and vocoid groups (trigger). In addition, any word in which the tensified form exists as a separate word (e.g., *sori* ‘sound’ and *s’ori* ‘loan word for ‘sorry’’) was avoided. A total of 120 words (4 categories * 5 targets * 6 triggers) were selected. Additionally, 87 words which frequently appear as tensified forms were used only for comparison.

The division between the non-tensification group (120 words) and the tensification group (87 words) was made based on the authors’ intuition. To confirm that the division was consistent with Korean speakers’ general intuition, we conducted Google searches where each word was entered in both non-tensified (so-called standard) and tensified forms. The search results were expected to be close to zero for the non-tensification group.

However, 12 out of 120 words categorized as the non-tensification forms showed more than 4 percent of tensified alternates and they were replaced by other words¹⁰. On the contrary, 11 words belonging to the tensification group were excluded because their proportions were all zero (the average of the others was 11.3%). Consequently, 120 and 76 words were on the final stimulus lists for the non-tensification and tensification groups, respectively.

39 Korean speakers participated in the survey experiment. They were college

⁹ In this paper, ‘second onset’ means the onset of the second syllable.

¹⁰ In contrast, 105 out of the 120 words had a less than 1 percent tensification rate (the average was 0.2% for the targets), consistent with the authors’ intuitions.

students at Chosun University (10 male and 29 female) and received credits for the participation. Their ages ranged from 20 to 26 with an average of 21.5. They were asked to judge how natural the tensified form of each word is compared to the non-tensified (so-called standard) counterpart. Each word was presented in both forms with a carrier sentence as exemplified in (5).

(5) Example

배가 많이 고프니 _____로 시켜라.

Order a double-the-ordinary-dish because I am very hungry.

곱빼기	(1)	(2)	(3)	(4)	(5)	곱빼기
kop'eki			'double serving'			k'op'eki

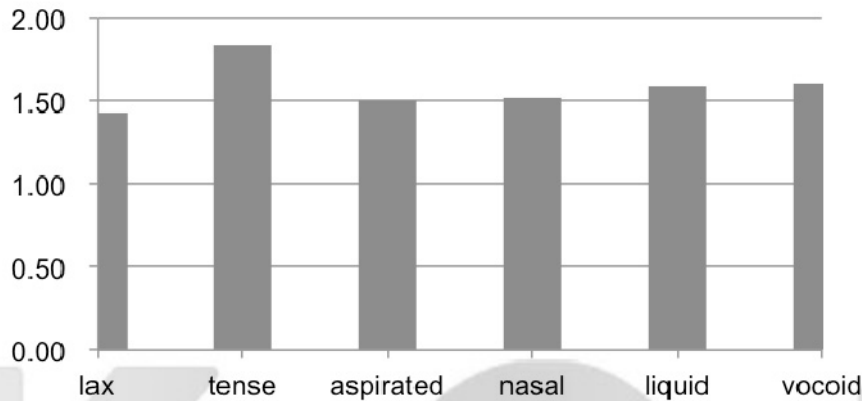
The participants chose one of the five scales according to their intuition. The instructions are given in (6).

(6) Instruction

- Only the left (non-tensified) form is good.
- Both are good, but the left form is better.
- Both are equally good.
- Both are good, but the right form is better.
- Only the right (tensified) form is good.

The higher the score, the more accepted the tensified forms were. The responses in the paper-based survey were transferred to a Microsoft Excel file, which was fed into SPSS for statistic analyses. The average rate was calculated for each word and the averages were subjected to one-way ANOVA to test the effects of the three variables (morphological category, target, and trigger). Before testing the main factors, the words belonging to the non-tensification group were compared with those belonging to the tensification group. As expected, the average was higher in the latter (1.58 vs. 3.07, $F(1,194)=275.5, p<.001$). This indicates that Korean speakers are more likely to accept the tensified forms of the words in the tensification group compared to the tensified forms of the words in the non-tensification group.

Figure 1. The average scores of word initial tensification according to the second onset type



At this point, we need to examine what factors influence the likelihood of word-initial tensification. In the non-tensification group, which was the critical stimuli, the word-initial tensification was not affected by the morphological category ($F(3,116)=.827$, $p=.482$). The average was higher in adverbs (1.65) and verbs (1.64) than in adjectives (1.58) and nouns (1.58) without statistical significance. The place of the word-initial consonant did not exert any influence ($F(2,117)=2.615$, $p=.077$), while the manner did ($F(2,117)=11.43$, $p<.001$). Tukey's post-hoc tests showed that there were no significant differences among places of articulation but the word-initial tensification of fricatives (1.86) and affricates (1.69) were more likely to be accepted than that of stops (1.44, $p<.001$ and $p=.022$, respectively). The effect of the second onset, which is the main concern of the survey, turned out to be marginally significant ($F(5,114)=2.215$, $p=.057$). Recall that the trigger (second onset) was classified into aspirated, lax, tense, liquid, nasal, and vocoid. The only significant difference was found between lax and tense types by means of multiple comparison by pairwise t-test adjusted by Bonferroni. Figure 1 shows that word-initial tensification is most accepted when the second onset is a tense consonant¹¹.

¹¹ When the responses themselves, not the means of each stimulus, were subjected to one-way ANOVA, the multiple comparison by pairwise t-test (adj. by Bonferroni) revealed that 'lax' group produced a significantly higher score than *every* other group ($p<.001$).

As in the non-tensification group, the morphological categories did not make any difference in word-initial tensification ($F(3,72)=0.548$, $p=.651$) for the words belonging to the tensification group. However, the average tensification rate was higher in adverbs (3.24) and verbs (3.20) than in adjectives (3.03) and nouns (2.94), consistent with the results for the non-tensification group. Neither the location ($F(2,73)=0.869$, $p=.424$) nor the manner ($F(3,73)=0.562$, $p=.580$) of the initial onset affected the likelihood of the word-initial tensification. Tukey's post-hoc tests did not show any significant differences. The effect of the second onset was marginally significant in the tensification group, too ($F(5,70)=0.325$, $p=.052$). The rate of tensification for the word-initial consonant was highest when the second onset was liquid (3.61) and second highest when it was a tense consonant (3.19).

To summarize, it was confirmed that the lexical effect is stronger than the phonological effect in word-initial tensification. As for the words in the tensification group which have already shown some degree of word-initial tensification, there are few phonological factors that affect word-initial tensification. However, when Korean speakers apply the process to new words, some phonological factors play a role in that the tense consonants in the second onset boost word-initial tensification, while lax ones inhibit it. This suggests that Korean has assimilation type laryngeal co-occurrence restrictions. It is also possible to account for the preference of the sequence of two tense consonants in terms of the regressive assimilation of [constricted glottis] similar to Ito (2014). In addition, fricatives and affricates are more likely to be tensified in word-initial positions than stops.

3.2 Lexical analysis of adverbialization

‘-i’ or ‘-hi’ is attached to an adjective to form an adverb in Korean. The selection of ‘-i’ or ‘-hi’ as an adverbial suffix is similar to word-initial tensification in that it has been assumed to be lexically determined. However, in the previous section, we showed that the laryngeal feature of a following consonant can affect the tensification of the *word-initial* lax consonants. Likewise, we investigate the possibility that the laryngeal feature of a preceding consonant can also affect the selection of the *following* aspirated (‘-hi’) vs. non-aspirated allomorphs (‘-i’).

For this purpose, we analyzed 371 trisyllabic adverbs that end with ‘-i’ or ‘-hi’.

From the National Institute of the Korean language (NIKL) corpus arranged in the order of frequency¹², we first sorted out 44 bisyllabic, 371 trisyllabic and 122 quadrisyllabic adverbs ending with ‘-i’ or ‘-hi’. Only trisyllabic adverbs were used in the analysis because the number of bisyllabic adverbs is too small and the quadrisyllabic adverbs are mostly compounds¹³. Of the 371 trisyllabic adverbs, 114 adverbs ended with ‘-i’ and 257 ended with ‘-hi’. The onsets of the first two syllables were grouped into lax, tense, aspirated, nasal, liquid, and vocoid, as they were for the judgment survey. The counts of all types are presented in Tables 2 and 3.

Table 2. Counts of two allomorphs according to the first onset (there were no aspirated and liquid onsets)

1st onset Suffix	lax	tense	nasal	vocoid	total
-i	65	25	13	11	114
-hi	150	12	40	55	257
total	215	37	53	66	371

Table 3. Counts of two allomorphs according to the second onset

2nd onset Suffix	lax	tense	aspirated	nasal	liquid	vocoid	total
-i	52	21	1	6	8	6	114
-hi	129	22	28	24	21	33	257
total	181	43	29	30	29	59	371

The next two tables (4 and 5) show the relative frequency of each combination in terms of O/E ratios¹⁴.

¹² Downloadable at http://www.korean.go.kr/front/reportData/reportDataView.do?mn_id=45&report_seq=1&pageIndex=1

¹³ For example, 56 quadrisyllabic adverbs were $\sigma\sigma\text{-}\textit{aps-i}$ ‘without $\sigma\sigma$ ’ and the last syllable of the stem (here, \textit{aps}) is regarded as the determinant of the allomorphs ‘-i’ or ‘-hi’.

¹⁴ O/E ratio is calculated by dividing observed counts by expected counts. O/E over 1 means that the pair is overrepresented while O/E under 1 means it is underrepresented.

Table 4. O/E ratios of two allomorphs according to the first onset

Suffix \ 1st onset	lax	tense	nasal	vocoid
<i>-i</i>	0.98	2.20	0.80	0.54
<i>-hi</i>	1.01	0.47	1.09	1.20

Table 5. O/E ratios of two allomorphs according to the second onset

Suffix \ 2nd onset	lax	tense	aspirated	nasal	liquid	vocoid
<i>-i</i>	0.93	1.59	0.11	0.65	0.90	1.43
<i>-hi</i>	1.03	0.74	1.39	1.15	1.05	0.81

O/E values in Table 4 show that ‘*-i*’ is more likely to be employed as the adverbializer suffix when the first onset is tense¹⁵. Table 5 also shows that ‘*-i*’ is more likely to be chosen when the second onset is tense. In both tables, chi-square tests revealed that lax, tense, and aspirated consonants show different distributions with ‘*-i*’ and ‘*-hi*’ ($p < .001$). That is to say, the adverbializing suffix ‘*-i*’ is more likely to be chosen as long as the tense consonant is somewhere in the stem. Then does the aspirated consonant in a stem also boost the selection of the adverbializing suffix ‘*-hi*’? Table 5 shows that the adverbializing suffix ‘*-hi*’ is preferred if the second onset is aspirated. On the other hand, the lax consonants do not prefer one allomorph over the others. Interestingly enough, nasals appear to have a preference for ‘*-hi*’. As a matter of fact, 11 stems carried both ‘*-i*’ and ‘*-hi*’ allomorphs (22 types, 5.9%) since the frequency data contain not only the so-called standard forms but the actually used forms. Then we need to calculate the O/E ratio on the basis of token frequency to find the actual strength of the tendency. Table 6 shows these values.

Table 6. O/E ratios of two allomorphs according to tense/aspirated onsets in stem

Suffix \ Stem onset	1 st tense	2 nd tense	2 nd aspirated
<i>-i</i>	3.55	3.59	0.04
<i>-hi</i>	0.38	0.37	1.23

¹⁵ There were no words whose initial onsets are aspirated or liquid.

The results in Table 6 reveal that the asymmetrical pattern between the two allomorphs is more noticeable than was presented in Tables 4 and 5. The differences in the O/E ratios between ‘-i’ and ‘-hi’ suffixes according to the consonant type in a stem are bigger in Table 6. Therefore, we can conclude that aspirated-aspirated pairs are preferred but that tense-aspirated pairs are avoided in the adverbialization, which also supports the existence of the assimilation type of laryngeal restriction.

Now the question is where these patterns originate from. Given that these two processes, i.e., word-initial tensification and adverbialization, are lexically determined in general, we can speculate that these results should reflect lexical statistics. Thus, we analyzed the lexical entries in Standard Korean Pronouncing Dictionary (H. Lee 2002).

3.3 Lexical analysis of Korean words

We have seen that the laryngeal feature of an onset may affect the change or the selection of the neighboring onset. Basically, if the onset is a laryngeally marked obstruent (i.e., tense or aspirated), the neighboring onset tends to be patterned with the laryngeal feature. To examine whether the entire Korean lexicon also exhibits this tendency, we analyzed the Standard Korean Pronouncing Dictionary because it provides the actual pronunciations of words, which might be different from the spelling. 67,258 lexical items in the dictionary were syllabified and onset-onset pairs in neighboring syllables were counted. The O/E ratios are presented in Table 7.

Table 7. O/E ratios of onset-onset pairs in neighboring syllables

$O_{n+1} \backslash O_n$	lax	tense	aspirated	nasal	liquid
lax	1.02	0.89	1.03	0.95	0.93
tense	0.91	1.22	1.02	1.08	1.33
asp	1.03	0.81	0.99	0.97	1.15
nasal	1.02	0.74	1.02	1.08	1.01
liquid	0.96	1.87	0.79	1.05	0.49

Table 7 shows that the ratio is around 1 in many cells, which means there is no preference for any specific onset-onset pair. However, it is notable that a tense onset consonant is more likely to be followed by tense and liquid consonants than lax,

aspirated, and nasal consonants. We conducted a chi-square test on obstruent-obstruent pairs, which gave birth to significant results ($p < .001$). This is, by and large, consistent with the results of the survey in section 3.1. The patterns in the lexicon suggest that the results from the judgment experiment regarding word-initial tensification are in line with the overrepresented patterns in the lexicon.

Word-initial tensification specifically deals with tensification of the word-initial consonant. Therefore, we need to examine the O/E ratios of onset-onset pairs in the word-initial position. The ratios in Table 8 are overwhelmingly high for words with tense-tense pairs in the first two syllables, which explains why the word-initial tensification is preferred when the second onset is also a tense consonant.

Table 8. O/E ratios of onset-onset pairs in the first two syllables of words

Word-initial onset 2 nd onset	lax	tense	aspirated	nasal	liquid
lax	1.03	0.91	1.01	1	0.96
tense	1.04	2.35	0.33	0.75	1.38
aspirated	1	0.95	1.07	1.02	0.86

We have shown so far that the fact that the tense consonants trigger a greater likelihood of word-initial tensification reflects lexical statistics. Let us now turn to the question of whether the patterns in the lexicon are also responsible for the asymmetrical patterns between the two adverbializer allomorphs: ‘-hi’ is more or less avoided when a stem has tense consonant(s) but is more likely to be applied when a stem contains aspirated consonants. The tense-aspirated pairs are underrepresented in the lexicon, which supports the relevance of the lexicon for the selection of allomorphs. However, Table 8 does not explain why the suffix ‘-hi’ is preferred when a stem has aspirated consonant(s) since aspirated-aspirated pairs are rarely overrepresented in the lexicon. The suffix ‘-hi’ is placed in the third syllable in the data and we closely examined the O/E ratios of aspirated-aspirated pairs in the second and third syllables of words in Table 9. However, Table 9 does not provide any evidence supporting the correlation between the lexical pattern and the preference of the suffix ‘-hi’ after the aspirated consonants.

Table 9. O/E ratios of onset-onset pairs in the second and the third syllables

$O_3 \backslash O_2$	lax	tense	asp	nasal	liquid
lax	1.01	0.98	0.99	1.01	1.00
tense	0.90	1.08	1.01	0.86	1.53
asp	1.07	0.93	0.98	1.04	0.77

Given that the suffix is ‘-*hi*’, we analyzed the data exclusively consisting of /h/ as opposed to an aspirated consonant as the third onset. Table 10 shows the O/E ratios of the onset of the second syllable with /h/ in the third syllable.

Table 10. O/E ratios of the second onset and /h/ in the third onset

$O_3 \backslash O_2$	lax	tense	asp	nasal	liquid
h	0.97	0.90	1.23	1.06	0.80

Table 10 clearly demonstrates that /h/ is overrepresented in the third onset when the second onset is an aspirated consonant. Then the preference of the suffix ‘-*hi*’ after the aspirated consonants can be explained by the lexical pattern.

To sum up, a close examination of the Korean lexicon reveals that tense-tense pairs are overrepresented but tense-aspirated pairs are underrepresented in the Korean lexicon. Then the results from the judgment survey of word-initial tensification and the avoidance of ‘-*hi*’ after the stems containing tense consonants can be explained by such lexical statistics. The preference of the suffix ‘-*hi*’ after the aspirated consonants is also explained on the basis of the Korean lexicon since the aspirated-/h/ pairs are overrepresented. Furthermore, we have shown that the relevant lexical patterns are position-specific since the overrepresentation of tense-tense pairs is prominent in the first and second syllables and that of the aspirated-/h/ pairs is prominent in the second and third syllables. These positions correspond to the sites where word-initial tensification and adverbializer allomorphy take place.

4. Discussion

Word-initial tensification and the selection of adverbializing suffixes in Korean are

gradiently constrained by laryngeal co-occurrence patterns. Such laryngeal co-occurrence restrictions are grounded on the distributional patterns in the lexicon. Both word-initial tensification and the selection of adverbializing suffixes in Korean are explained by the general tendency that a marked laryngeal feature (tense or aspirated) in a word increases the likelihood of the appearance of the same feature within the word but decreases the appearance of a different feature. Analysis of the Korean lexicon produced similar patterns for all features except for aspirated-aspirated pairs, which are not overrepresented. In Table 11, the results are summarized and compared with those presented by Ito (2014).

With the results summarized in Table 11, we will discuss the type of laryngeal restrictions found in Korean (section 4.1), the implication of the results for the laryngeal co-occurrence restrictions (section 4.2), and the interaction of the laryngeal co-occurrence restrictions with the three-way laryngeal contrast in Korean (section 4.3).

Table 11. Results of the judgment survey and lexical analysis in comparison with Ito's (2014)
(‘▲’ stands for ‘more likely’, ‘▼’ ‘less likely’ and ‘=’ ‘no tendency’)

	Present study			Ito (2014)	
	Word-initial tensification	-i/-hi allomorphy	Whole lexicon	Compound tensification	Simple nouns
Tense-tense	▲	N.A.	▲	▼	▲
Tense-asp asp-tense	= / N.A.	▼ / N.A.	▼ / =	▼ / ▼	▼ / ▼
Asp-asp	N.A.	▲	=	N.A.	▼

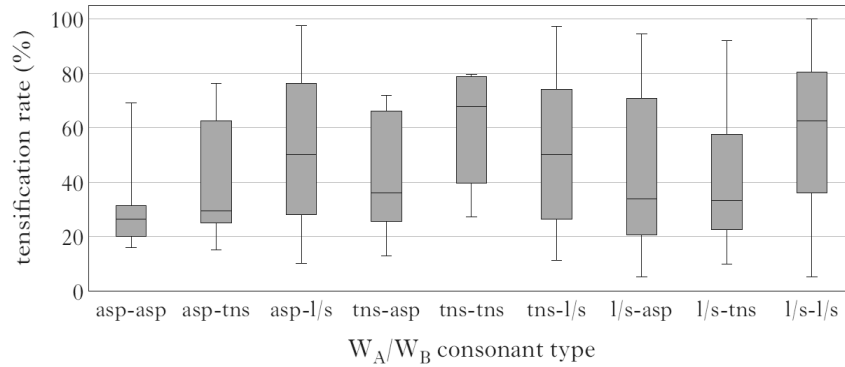
4.1 Type of laryngeal co-occurrence restrictions in Korean

The tendencies in Table 11 are not very clear except that mixed pairs containing tense and aspirated words are avoided. The general pattern in the lexicon appears to affect the two procedures of interest in this paper. Based on the results of this study, we argue that Korean has the assimilation type of laryngeal co-occurrence restrictions in contrast to Ito (2014). First of all, tense-tense pairs are overrepresented in the entire lexicon and in simple noun lexicons. Furthermore, a tense consonant facilitates the tensification of the preceding (word-initial) lax consonant in word-

initial tensification. If our claim is on the right track, why is the compound tensification less likely to occur when the base words already contain a tense consonant (Zuraw 2011, Ito 2014)? We speculate that it has to do with a boundary effect. Note that the laryngeal co-occurrence restrictions (OCP in a broad sense) are placed cross-linguistically within a domain, which is usually a root or a word. Assuming that compound tensification aims to signal the boundary between the two component words, tensification before or after another tense consonant may obscure the boundary. Tense-tense pairs are preferred *within* a word¹⁶. Thus, if compound tensification applies when any component word carries a tense consonant, it may induce the wrong interpretation of the word as a single word rather than as a compound consisting of two component words on the part of listeners.

Ito (2014) claims that Korean has the dissimilation type of laryngeal co-occurrence restriction. She accounts for the overrepresentation of tense-tense pairs in the lexicon in terms of regressive assimilation. This direction-based assimilation account appears to work for word-initial tensification and the direction of the effect is regressive. However, a closer examination of the results in Ito (2014) suggests that this is not the case.

Figure 2. Compound tensification rate as a function of W_A and W_B consonant types (35 speakers, 1171 words) ('asp-asp' means that both W_A and W_B contain aspirated consonants; 'l/s-tns' means that W_A contains lax/sonorant consonants and W_B indicates tense consonants (Ito 2014: 368).)



¹⁶ This is also proposed for Japanese rendaku (Sano 2015).

Figure 2 shows the tensification rate in compounds as a function of the consonant types in the first and second nouns. If we assume that Korean is characterized as the dissimilation type of laryngeal restriction but has a regressive assimilation of the tense feature similar to Ito (2014), the tensification rate should be higher when the second noun contains a tense consonant than when the first noun contains one. However, comparison of the sixth (tense-lax/sonorant) and the eighth (lax/sonorant-tense) bars, as well as the second (asp-tns) and the fourth (tns-asp) bars does not meet this expectation. Rather, it is close to the opposite. Also, the tensification rate is the highest when both words contain tense consonants, which is contrary to Ito's account. Another result to note is that the closer a tense consonant is to the site of compound tensification, the higher the tensification rate is as shown in Table 12.

Table 12. Compound tensification rate as a function of position of W_A consonant type (Ito 2014: 369)

consonant type	position	tense	lax	total
aspirated	local	465 (54%)	396	861
	non-local	122 (51%)	115	237
tense	local	432 (45%)	522	954
	non-local	436 (39%)	675	1111

Table 12 shows that the tensification rate is significantly higher ($\chi^2=7.44$, $df=1$, $p=0.0064$, Ito 2014: 369) when a tense consonant is adjacent to the target of compound tensification. We interpret this locality effect as evidence that Korean does not have the dissimilation type of laryngeal restrictions but rather, the assimilation type.

Aspirated consonants behave in a more complicated manner. On the one hand, the lexicon evidences no tendency (whole vocabularies) or underrepresentation of aspirated-aspirated pairs (simple nouns)¹⁷. On the other hand, aspirated consonants are more likely to contain /h/-containing allomorph, i.e., ‘-hi’, in the adverbialization.

¹⁷ A language may have different subgrammars depending on lexical strata (Itô and Mester 1995) or morphological levels (Inkelas and Orgun 1995). Korean has different lexical strata (pure Korean, Sino-Korean, and loanwords) and accordingly, different phonologies (e.g., S. Park et al. 2013, N. Park 2015) similar to Japanese. This fact suggests that the laryngeal co-occurrence restrictions may apply differently at these lexical strata in terms of whether and how they affect the lexical items.

These results indicate that a more elaborate analysis of the Korean lexicon is needed. A lack of apparent patterns for the aspirated-unaspirated pairs in the entire lexicon might be due to the presence of many Sino-Korean words. Above all, Sino-Korean words, which are longer than one syllable, are basically compounds that are formed by a combination of two or more monosyllabic morphemes. Therefore, Sino-Korean words are expected to be free of laryngeal co-occurrence restrictions. In addition, Sino-Korean words do not contain tense consonants, whereas they contain many aspirated consonants.¹⁸ Consequently, the patterns of aspirated consonants in the lexicon might be erased by the dominant Sino-Korean words.¹⁹ To summarize, our results, by and large, prove that Korean has an assimilation type restriction on laryngeal features with a few inconsistent pieces of data, which should be investigated more thoroughly in the future.

4.2 Are the laryngeal restrictions only static?

Laryngeal co-occurrence restrictions, or segmental OCP, are treated as static restrictions rather than dynamic ones. Even in languages with categorical (or obligatory) restrictions on laryngeal features in the lexicon, there are few dynamic (morpho-)phonological procedures where the restrictions actively play a role. However, Zuraw (2011) cast doubt on the view that laryngeal co-occurrence restrictions are static by showing a tendency of tense consonants to correlate negatively with the rate of compound tensification in Korean. Her claim was examined more closely by Ito (2014), who argued that the dissimilation type of laryngeal restriction plays a role in compound tensification in Korean. The present study also demonstrates that laryngeal co-occurrence restrictions apply to word-initial tensification and allomorph selection, although the effect is not absolute.

However, it is too early to confirm that laryngeal restrictions are at play in completely dynamic procedures. Most of all, the three procedures in Korean, i.e., compound tensification, word-initial tensification and the selection of adverbializing suffixes, are lexically determined. This means that the laryngeal restrictions for these

¹⁸ There are only three exceptions: 氏 [s'i] 'Mr.', 雙 [s'an] 'pair', and 喫 [k'ik] 'to eat'.

¹⁹ According to C. Kim (2010), 68.99% of words in the Korean Standard Unabridged Dictionary (published by the National Institute of the Korean Language) contain Sino-Korean morphemes.

processes can be influenced more by other factors than phonological constraints. For instance, Gallagher (2010) argues that these restrictions make *roots* more distinguishable from each other but they are not involved in derived or inflected forms. Assuming that the tensified form and the adverbialized form are stored as separated lexemes in the lexicon, the patterns might be motivated by word-distinctiveness as Gallagher argues. Nevertheless, the judgment survey in this study, as well as the wug tests in Ito (2014), shows that the restrictions in the lexicon can be extended to new lexical items. We also showed that the laryngeal restrictions affect a morphophonological process (adverbialization), which suggests that they may influence other productive processes. This is open for future research.

We need to pay attention to the implication of these results with regard to the origin of the laryngeal co-occurrence restrictions. As noted, the laryngeal co-occurrence restrictions are known to be static, which gives rise to a question about the origin of the lexical patterns. If they are fully static (if they do not apply to dynamic procedures), how can the lexicons have these patterns? Several hypotheses have been proposed to account for the OCP patterns. Ohala (1981, 1993, 2003) argues that when a listener hears a sound twice in a specific domain, s/he might perceive either instance as the result of a coarticulation of the other. Consequently, s/he would (hyper-)correct the sound into a different one in the mental representation. On the basis of this ‘Coarticulation Hypercorrection Hypothesis’, Frisch (2004) argues that words containing similar segments are difficult to process and the difficulty motivates the OCP. H. Kang (2015) also shows that words containing similar segments are difficult to memorize. These studies directly account for why dissimilation type restrictions appear in the lexicon. Then how do assimilation type restrictions arise? They can also result from the effect of coarticulation. When the acoustic cue of laryngeal feature is elongated into neighboring segments, the neighboring segments can be perceived as marked with the feature. So the restrictions in question are motivated by the ‘parsing’ problem that listeners may experience. In addition to the above, this study presents another way that the patterns emerge in the lexicon. Though they are not totally productive, some morphophonological processes contribute to the rise of the patterns. We cannot determine the order of precedence, but the static patterns and the dynamic procedures affect each other. We can predict that there will be more procedures where laryngeal co-occurrence restrictions are involved.

4.3 The two marked features in Korean: tense and aspirated

Table 11 shows that tense-aspirated (and aspirated-tense) pairs are generally not preferred in Korean, though the avoidance is not manifested everywhere. This is not surprising since Gallagher's (2010) typological study exactly predicts this pattern. If Korean has any laryngeal co-occurrence restrictions, the two marked features are expected to avoid each other in a word. It does not matter whether the restriction is of an assimilation or dissimilation type. In an assimilation type language, consonants in a word should have the same marked feature if any exists. In a dissimilation type language, a word should have only one consonant with a marked feature. These patterns result from the typologically unusual three-way contrast among obstruents in Korean. They also make us predict that two marked laryngeal features will be less likely to appear in a word in languages that have a certain type of laryngeal co-occurrence restriction.

Assuming that Korean has assimilation type restrictions, what interests us is that tense and aspirated show different patterns in the lexicon. While a tense consonant is likely to appear with another tense in the lexical items, aspirated consonants show no or the opposite pattern in the lexicon. Tense consonants manifest assimilation type restrictions but aspirated ones do not show any specific patterns. How do we account for these different patterns between aspirated and tense consonants in the Korean lexicon? As noted, aspirated consonants appear in both native and Sino-Korean words, which may prevent the restriction-observing patterns from standing out in the lexicon. Additionally, the two marked laryngeal consonants may differ from each other in terms of the difficulty in articulation, though they share many phonetic features in comparison with lax consonants, such as higher F0 on the following vowel (T. Cho et al. 2002, M. Kim and Beddor 2002, Y. Kim 2004, Y. Kang 2014, etc.) and longer closure duration (Pyo 1975, S. Choi and Jun 1998, S. H. Kim 1999). However, aspirated consonants show higher oral pressure and airflow than tense consonants, as well as higher relative burst energy (T. Cho et al. 2002). With the longest VOT duration, these phonetic features of aspirated consonants imply that they are the least easy consonants to articulate in Korean. For now, we speculate that this is the reason why aspirated-aspirated pairs are less common than tense-tense pairs in the lexicon²⁰.

²⁰ Gallagher (2015) points out that long VOT, which applies to both aspirated and ejectives,

5. Conclusion

LCR are known as static constraints in the lexicons of many languages, which are concerned with the well-formedness of roots (MacEachern 1999, Gallagher 2010). While the static aspects of the restrictions receive significant attention and are well studied, only a few studies have reported the dynamic aspects so far (Ito 2014, for example). If the restrictions are not found in dynamic processes at all, it would be puzzling to account for how so many roots are in compliance with the restrictions in the lexicons of languages. This study shows that the LCR actively plays a role in word formation in the Korean lexicon, with two (semi-) dynamic processes: word-initial tensification and adverbializer allomorphy. In addition, we showed that the dynamic processes interact with the static patterns in the lexicon.

By conducting a survey experiment on word-initial tensification, we found that tense consonants boost the rate of word-initial tensification. An analysis of Korean lexicon revealed that the /h/ is more likely to occur after an aspirated consonant in Korean, which is consistent with our finding that adjectives containing aspirated consonants prefer ‘-hi’ to ‘-i’ in adverbialization. In such a way, LCR in phonological and morphological processes in Korean reflect Korean lexicon statistics. Furthermore, based on the results of this study, the Korean language appears to have the assimilation type of laryngeal constraints.

The fact that LCR is active in word-initial tensification and the selection of adverbial suffixes suggests that LCR is also dynamic. The dynamic aspect of LCR interacts with the static (or lexical) aspects, resulting in similar patterns. The remaining question is about the two laryngeally marked features in Korean. It should be determined whether the two features behave similarly in terms of LCR through a detailed analysis of the Korean lexicon. If not, it also should be investigated what makes such a difference between the two.

APPENDIX. Stimuli for Judgment Survey

word	gloss	part	word	gloss	part
teite ^h akwi-ta	to twitter	verb	teate ^h is	if (the worse comes)	adv
teete ^h i-ta	to put aside	verb	teant'uuk	heavily	adv
teuŋ ^h ak ^h ari-ta	to mutter	verb	teallo	automatically	adv
teik' ^h ari-ta	to gabble	verb	te ^h teallo	automatically	adv
te ^h mul-ta	to end	verb	teauki	thickly	adv
tearu-ta	to cut	verb	teamos	very	adv
seu-ta	to raise	verb	salp ^h osi	softly	adv
sakwi-ta	to make friends	verb	sulte' ^h ak	secretly	adv
soksaki-ta	to whisper	verb	salmjasi	stealthily	adv
samk ^h i-ta	to swallow	verb	salkum ^h ani	furtively	adv
sumj ^h atul-ta	to permeate	verb	saruruuk	gently	adv
salle-ta	to flutter	verb	swi ^h amswi ^h am	with frequent rests	adv
tuullu-ta	to stop by	verb	turu ^h ur ^h an	snoring loudly	adv
tamul-ta	to close	verb	tomutei	entirely	adv
tak'talha-ta	to scold	verb	tete ^h uŋ	roughly	adv
tate ^h i-ta	to be hurt	verb	tuump'uk	quite a lot	adv
towateu-ta	to help	verb	tuums ^h an ^h tuums ^h an	sparsely	adv
tamku-ta	to soak	verb	t ^h uk	further	adv
k ^h anil-ta	to wander	verb	kik' ^h ai	willingly	adv
k ^h anturi-ta	to touch	verb	kaman	still	adv
karu-ta	to separate	verb	k ^h atup	again	adv
kjausk ^h ari-ta	to peek	verb	k ^h alp ^h ishamjan	too often	adv
kamte ^h u-ta	to hide	verb	korekore	in a loud voice	adv

kap'atei-ta	to gasp	verb	kjau	merely	adv
posalp ^{hi} -ta	to take care of	verb	pajahuuro	at the height	adv
pj ^{arui} -ta	to contemplate	verb	pulk'uiun	firmly	adv
p ^{amuri} -ta	to mix together	verb	puti	by all means	adv
pik'o-ta	to twist	verb	palk ^{hak}	all of a sudden	adv
pup ^{hul} -ta	to expand	verb	pururuu	trembling	adv
piu-ta	to empty	verb	p ^{anjanhi}	clearly	adv
teamulswe	lock	noun	teaukha-ta	to be dense	adj
teurumsal	wrinkle	noun	teote ^h olha-ta	to be tidy	adj
teant'antei	calf	noun	teeps'a-ta	to be quick	adj
teopasim	uneasiness	noun	teikj ^{ap} -ta	to be boring	adj
teip ^{haji}	cane	noun	teiruha-ta	to be tedious	adj
teojaktol	pebble	noun	teomateomaha-ta	to be nervous	adj
sote'akse	screech owl	noun	si ^{ng} ap-ta	to be dull	adj
sutcepi	soup with dough flakes	noun	sar ^{ap} -ta	to be sorrowful	adj
sojongtori	whirlpool	noun	sat ^h uruu-ta	to be clumsy	adj
sortum	gooseflesh	noun	salt'tulha-ta	to be thrifty	adj
sanjanj	hunting	noun	sanjanjanha-ta	to be gentle	adj
sat ^h uri	dialect	noun	s ^{un} ha-ta	to be regrettable	adj
tot ^h ori	acorn	noun	tetanha-ta	to be amazing	adj
t ^{awi}	hot weather	noun	turj ^{ap} -ta	to be afraid	adj
tosorak	luncheon	noun	tumul-ta	to be rare	adj
turepak	well bucket	noun	t ^{aps} -ta	to be most	adj
tek'u	back talk	noun	talk ^h omha-ta	to be sweet	adj
tomapem	lizard	noun	tuls' ^{ak} ha-ta	to be turned up	adj
k ^{aul}	mirror	noun	kap'unha-ta	to be light	adj
kamasot ^h	kettle	noun	kotalpu ^h -ta	to be tired out	adj

kjʌtʉrʌŋi	armpit	noun	karyʌp-ta	to be itchy	adj
kirʌki	wild goose	noun	kojakha-ta	to be nasty	adj
kop'i	bridle	noun	kanuul-ta	to be thin	adj
kʌp ^h um	bubble	noun	kwite ^h anh-ta	to be troublesome	adj
pakuni	basket	noun	purʌp-ta	to be jealous	adj
pak'at ^h	outside	noun	pamnuwɛ-ta	to be late at night	adj
panuul	needle	noun	pijʌlha-ta	to be sordid	adj
poram	worth	noun	pʌkte ^h a-ta	to be too much	adj
paŋaswe	trigger	noun	puls'aŋha-ta	to be miserable	adj
pete ^h u	cabbage	noun	pankap-ta	to be glad	adj

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34 Hijo Kang · Mira Oh

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