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Tonogenesis in Korean

A thesis submitted in partial fulfillment of the requirement
for the degree of Bachelor of Arts in Linguistics from
The College of William and Mary

by

Cameron Henshaw

Accepted for Honors

(Honors)



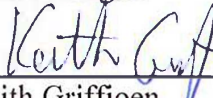
Anya Linden, Director



Jack Martin



Kate Harrigan



Keith Griffioen

Williamsburg, VA
July 30, 2018

Tonogenesis in Korean*

1.0 Introduction and Background

Abstract

The Korean language appears to be in a transitory state, with some evidence supporting the emergence of a phonemic tonal contrast, and other evidence pointing more towards phonetic variation in vowel pitch. Most theories of tonogenesis are based upon the idea that consonants influence the sounds around them, which makes Korean a particularly interesting case due to its unusual series of three-way contrasting consonants. This paper traces the trajectory of Korean's consonants over the last century, investigates evidence for and against an emerging tonal contrast in Korean, and describes my own parallel experiment in English and the implications it has on our understanding of tone in Korean. I conclude that Korean is in a very late stage of tonogenesis.

1.1 Tone and Tonal languages

Tone can be used in a variety of ways in different languages, and can have several determining factors. Tone refers to the pitch of a vowel, and indicates that the pitch of the vowel is somehow important perceptually. Vowel pitch is predominantly caused by the state of the vocal folds; if they are stretched and under tension, a high pitch is produced, while if they are slack and under less tension, a lower pitch will be produced. Air flow through the vocal tract can also influence pitch however; an increase

* Thanks to the Cell Working Group Summer 2018 for helpful comments and discussions, and to Professor Anya Lunden for her guidance and encouragement. Any mistakes are my own.

in airflow can cause a high pitched vowel (Ladefoged 2010). Pitch can be influenced by certain vocal fold states. For example, a low pitch can be caused by creaky voice.

In some languages, differing pitch can be used to distinguish words from one another. This use of pitch is called tone, and languages that possess it are called tonal languages. An example of a tonal language would be Mandarin Chinese, when saying the syllable [ma] with a high and level tone has one meaning, but pronouncing [ma] with a high and falling tone has another meaning. Tonal languages are found throughout the world; other examples include Shona (a Bantu language), Navajo (an Athabaskan language), and Thai (a Kra-Dai language).

An important distinction to make in the discussion of tone and pitch is the difference between phonetic differences and a phonemic distinction. The sounds we pronounce may vary in different ways for a variety of reasons; either due to neighboring sounds influencing them, where they are in the sentence, or simply because we are unreliable speech producers. These differences are called phonetic differences; they do not change how we perceive the sound overall. A phonemic difference, on the other hand, refers to the difference between two sounds that are perceived to be entirely separate sounds. The sounds [b] and [p] have a phonemic difference in English, as English speakers distinguish them in words. It is this phonemic contrast that allows us to distinguish the words “staple” [stepl] and “stable” [steb]. However, this phonemic difference does not hold in all other languages; there are languages where [b] and [p] are perceptually taken to be one sound in the minds of speakers (as in Plains Cree). This distinction of phonetic and phonemic differences will play a crucial component in the ensuing discussion of the state of pitch and tone in Korean.

1.2 Korean Background

The consonant inventory of Korean is given in (1).

(1) Consonant Inventory of Korean¹

	Bilabial	Alveolar	Velar	Glottal
Stops	p p* p ^h	t t* t ^h	k k* k ^h	
Affricates		tʃ tʃ* tʃ ^h		
Fricatives		s s*		h
Nasals	m	n	ŋ	
Liquids		r		

A significant portion of these consonants are part of Korean's unique series of three-way contrasting consonants; the bilabial (p, p*, p^h), alveolar (t, t*, t^h), and velar (k, k*, k^h) stops, as well as the affricate (tʃ, tʃ*, tʃ^h) consonants. Stops are a category of consonant that are produced by stopping the airflow, and then releasing it in a burst. Affricates are similar, containing a stop portion released into a constricted airway creating frication. The Korean consonant series are unique among the sounds of the world, as the three-way voiceless contrast is not one that has been reported in any other language. For example, in French consonants such as [t] and [d] contrast based upon the voicing feature; this is a fairly typical consonant contrast. Mandarin Chinese has a phonemic aspiration contrast; the voiceless unaspirated [t] contrasts with the

¹ There is some debate on the status of glides in Korean; as they aren't relevant to the discussions of tonogenesis in Korean, I have left them out of the consonant chart.

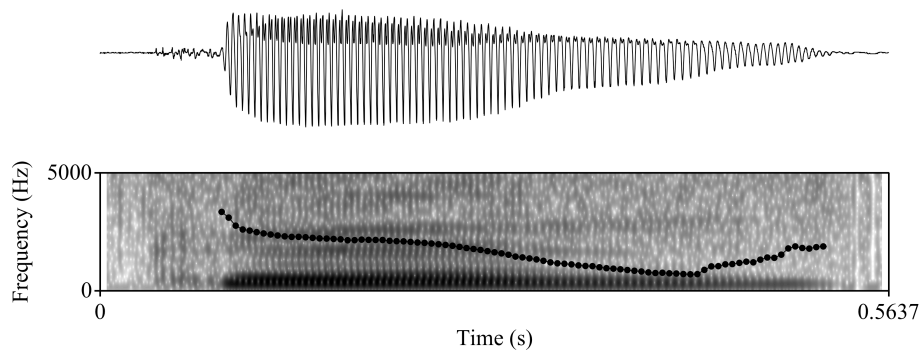
voiceless aspirated [t^h]. Many other languages have two-way contrasting consonants as seen in these examples, but I am unaware of any other language that has a three-way series of voiceless contrasting stops. The unique three-way contrasting Korean consonants are not fully understood, and their properties have been the subject of much debate. There is still little consensus on the underlying contrasting feature(s) of these consonants, but it is clearly more complicated than the two-way contrasting consonants seen in, for example, French, Mandarin, and many other languages. The two contrasting features mentioned above are also integral in the discussion of tonogenesis in Korean. Voicing refers to the state of the vocal folds during the production a sound; if the vocal folds are vibrating, a sound is said to be voiced, while if they are open and not vibrating, the sound is said to be voiceless. Aspiration can also distinguish sounds from one another; this trait refers to the puff of air after the initial release of a consonant. Aspiration differs from Voice Onset Time (VOT), which refers to the amount of time it takes for voicing to begin after (or in voiced consonants, before) the stop release. As the consonants I am discussing are all voiceless, the terms VOT and aspiration are used interchangeably unless noted otherwise.

The term 'fundamental frequency' (f₀) is also relevant to Korean consonant realizations; f₀ refers to the fundamental frequency, which corresponds to the perceived pitch of the vowel. Also relevant is a voice quality called breathy voice, which is often measured by subtracted the second harmonic from the first harmonic (H₁-H₂). Although both of these traits occur on vowels, they are actually determined by the preceding consonants in Korean. These traits, and others we may not be aware of, could be important perceptual cues to the identification of the surrounding consonants.

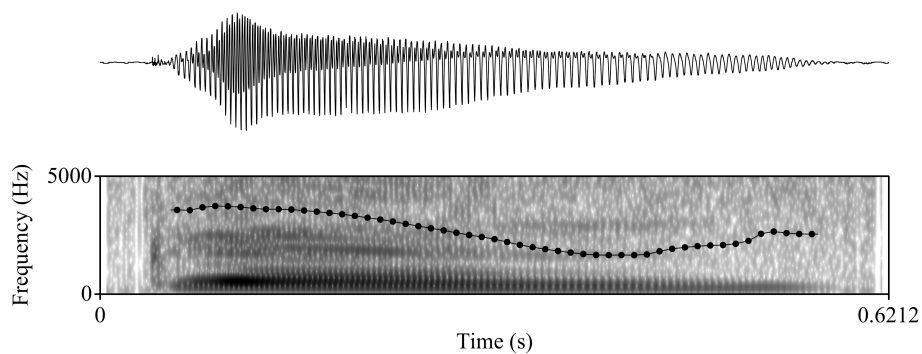
In (2), the spectrograms and waveforms of the three different consonant types are presented. The first type, lenis is shown in (A), sometimes called lax, which canonically has been characterized by a moderate amount of aspiration and is followed by a lower pitched, often breathy vowel (Kim et al 2002). In the following example, the aspiration length of the lenis consonant is actually comparable with that of the aspirated consonant. This is a more recent change in the language, and will be discussed in depth in section 3.2. The type of consonant, shown in (B), is a fortis consonant, sometimes called tense; this consonant is characterized by having no aspiration and a following vowel with a higher pitch, as seen in the spectrogram pictured. Fortis consonants are denoted with an asterisk. The third type of consonant, seen in (C), is aspirated and also followed by a vowel of high pitch. (Cho et al. 2001). They are typically denoted with a superscript 'h.' It is important to note that the descriptions of these consonants refer to the properties of each when they are in the initial positions of accentual phrases (APs), a unit of prosodic structure in Korean. The consonants act differently when they appear phrase and word medially (Jun 1993). The initial AP position is assumed for the rest of this paper.

(2) Korean consonant spectrograms and waveforms

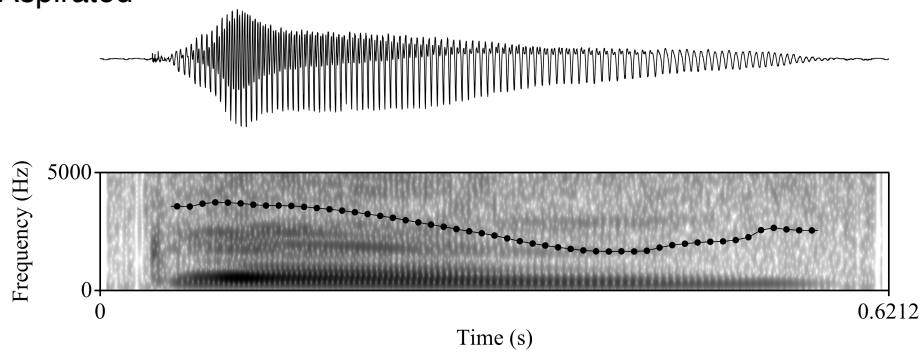
(A) Lenis



(B) Fortis



(C) Aspirated

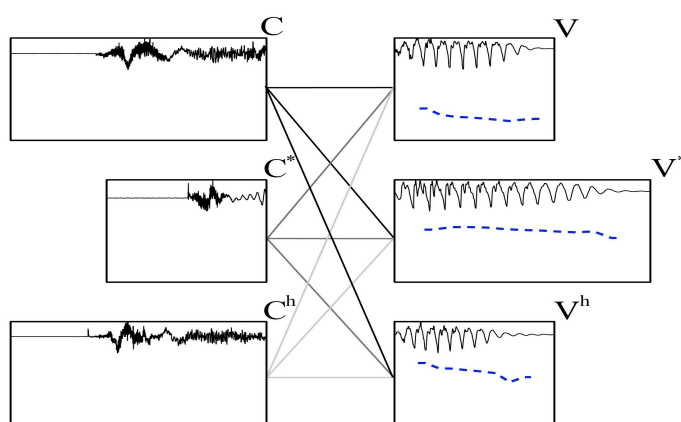


1.3 Pinning down Perceptual cues

Given the unique properties of the three-way contrasting consonants in Korean, linguists have made many efforts to determine which perceptual cues are most

important for the recognition of each consonant type. Kim et al. (2002) performed an experiment which involved cross splicing Korean words so that different vowel and consonant pairs were put together. This experiment's purpose was to determine the relative importance of perceptual cues on the vowel portion versus those on the consonant portion. It seems likely that vowel pitch is a very important perceptual cue to consonants due to the substantial differences in the pitches of the vowels following different consonant types. The aspiration ranges of the aspirated and lenis consonants have also begun to overlap in recent years, meaning that these consonant portions have lost at least one important perceptual cue.

(3) Cross-splicing consonants and vowels



As seen in (3), the vowel and consonant portions were cut apart, then rematched in a cross-splicing method of preparing stimuli. For example, the lenis consonant on the first row was paired with the “fortis” vowel in the second row. The vowels are marked with the same symbols as the consonants and I often refer to them as a consonant type,

such as “fortis,” or “lenis.” This is not to imply there are different vowel types, but instead is a short hand to indicate which consonant the vowels originally followed. Each consonant was paired with the different vowels listed. These stimuli were then played for native Korean speakers in a Forced Multiple Choice test, and the listeners chose which word they heard. In the original production, the initial consonants influenced the vowels that followed them; therefore when the vowels were matched with different consonants, the listeners were actually hearing perceptual cues for two different consonant types. Kim et al. found that in many cases listeners identified the consonant type based on which consonant the vowel had originally followed, instead of which consonant was actually present. This was true for all stimuli in which there were vowel portions that had originally followed lenis consonants, and had either fortis or aspirated consonants spliced before the vowels. It seems likely that the pitch of the vowels originally following lenis consonants is an important cue, as these vowels were pronounced with a much lower pitch than the vowels following the other two consonants. Although the pitch was not the only possible prominent feature, it is likely that it was a key component in the listeners’ identification of the consonant as lenis. When the cross-spliced words contained parts from the aspirated and fortis consonants, the listeners instead based their identification on the consonant portion present (Kim et al. 2002). This is likely due to both of these consonants types being followed by a vowel with a higher pitch, thus the consonant portions containing aspiration (or lack of) was a stronger identifying cue. Henshaw and Lunden (2017) found similar results when they replicated this experiment with the [tʃ] series.

Although the study by Kim et al. demonstrated that the vowels following these consonants are extremely important to identifying the consonants, it is not clear which vowel property listeners are using to distinguish the sounds. It seems very likely that vowel pitch is an important perceptual cue for listeners, as the pitch is quite noticeably different, but it is difficult to isolate the pitch from other possible cues in the vowel portions. It is also possible that the voicing quality of the vowel, such as the breathy voice following lenis consonants, could also be a perceptual cue to consonant type. It is clear however that the studies discussed highlight the importance of the perceptual cues located in the vowel portion of words. While the specific acoustic properties of the vowel which gave rise to the vowel-based identifications are unclear, the discussed experiments do raise the strong suspicion that pitch is crucial component of consonant identification and suggests the language may be becoming tonal. Due to Korean's unique consonant contrast, if Korean were to become fully tonal it would likely develop a two-way tonal contrast, with high tones following the consonants that are fortis and aspirated, and a lower tone following originally lenis consonants. If this did occur however, it seems likely that there would remain a two-way consonantal contrast between the fortis consonant and a singular consonant formed by the merger of the lenis and aspirated consonants. We already have some evidence supporting this, as the VOT ranges of the lenis and aspirated consonants have already begun to overlap. This will be discussed further in section 3.2.

2. Tonogenesis

2.1 General Tonogenesis

The emergence of tone is generally thought to arise from consonantal contrasts and their effect on the surrounding vowels. As consonants influence the sounds around them, these phonetic differences can gradually become more and more pronounced until they lead to a phonemic tone contrast. Different consonantal aspects such as voicing, aspiration, and glottalization have been proposed to induce tonal contrasts, and subsequently be replaced by them (Kang 2014).

One classic account of tonogenesis is that of Vietnamese by Haudricourt in 1954. In his account, both initial and final consonants played an important part in the tonogenesis process, with initial consonants influencing tone height and final consonants influencing tone contour. Although the tonogenesis process in Korean seems to be relying only upon the syllable initial consonants, the overarching principle still appears to hold.

Kang (2014) describes five stages of tonogenesis based on Maran (1973). In the early stages, consonants with a VOT contrast would gradually influence the vowels around them, resulting in one consonant type followed by a high pitched vowel and one by a low pitched vowel. This phonetic difference was enhanced more and more until the pitch ranges of the vowels no longer overlapped. At this point, the VOT ranges of the consonants would gradually begin to overlap. Overtime they became more and more similar, until the VOT of the consonants was the same, and the distinguishing feature was the pitch of the following vowel. This pitch became the phonemic contrast between the two consonant and vowel pairs; therefore a tonal contrast was acquired. In stage 1,

a language has two consonants that differ in VOT. In stage 2, the f_0 of the vowel following these consonants begins to differ, and in stage 3, the consonants differ in both VOT and f_0 . The VOT ranges of the consonants then begin to overlap in stage 4, and then completely merge in stage 5, producing two consonants which differ only in f_0 of the following vowel.

2.2 Tonogenesis in Korean

As the VOT ranges of the lenis and aspirated Korean consonants have begun to overlap, it would seem that Korean could be characterized as being at stage four in the above model of tonogenesis. However, when looking at more data it becomes apparent that categorizing Korean is somewhat more complex. Kang (2014) took measurements of Korean speakers of different ages, and found that the loss of the VOT distinction and the emergence of the f_0 distinction seem to have taken place at least somewhat concurrently. It seems that tonogenesis in Korean may not be able to be divided into such neat stages. In the model described by Kang (2014), based upon Maran (1973), we do know the language has both consonants with overlapping VOTs and differing pitch in the vowels following these consonants. This suggests that Korean is in an advanced stage of tonogenesis, or has already gained a phonemic tonal distinction. Before or during the emergence of the vowel f_0 contrast, the VOT range of two of the consonants began to overlap. It is possible that this overlap caused the lenis and aspirated consonants to become too similar to each other, and the language reacted by emphasizing the f_0 differences of the vowels following these consonants in order to make them more distinguishable. This is not the whole picture however; the fortis

consonant also began to be pronounced with a high f0 of the following vowel, even though it was easily distinguishable from both the other consonant types due to its short VOT.

It is difficult to determine the exact status of Korean's potential tonal contrast for another reason as well; sound changes happen gradually, and it is a challenge to determine when sound characteristic becomes contrastive in a language. In other words, it can be difficult to draw the line between a phonetic difference and a phonemic distinction, and there seems to be little data available on how to categorize a sound property when it is ambiguous.

3. Vocal Fold Tension as Pitch Contrast Catalyst

3.1 Kingston's Account of Athabaskan

One pertinent study with strong phonetic motivation is Kingston's (2005) paper dealing with Athabaskan languages. This language family is an interesting case to compare with Korean, as different Athabaskan languages formed different tones in the same environments (i.e. some languages formed high tone where others formed low and vice versa). Kingston's account demonstrates the complexity of tonogenesis, and how different outcomes can occur from the same starting point.

The graphic in (4) illustrates the proposed path of tone in Athabaskan languages.

² In Kingston's account, stem final consonants in Athabaskan languages used to have a glottalic and non-glottalic contrast, and seen in the Pre-tonogenesis column.

(4) Athabaskan path³

Pre-tonogenesis	1. Coarticulation	2. Loss of Glottalization	3. Language split, tense vs creaky voice	4. Tone emerges based on voicing of vowel
takʔ	-> taʔkʔ	-> taʔk	ta'k	-> ták
			tək	-> tàk
tak		->		ták or tàk

The tonogenesis process began when the glottal articulation of the consonants spread to the preceding vowel, causing distinctive glottalized (or constricted) voice qualities, shown in the first row in stage 1. The stem final consonants then lost their glottalic articulation, and the words contrasted based solely on the voicing quality of the vowel. This is seen in column 2, where the word with a glottalized vowel contrasts with the plain, unchanged word in the second row. Here Athabaskan languages split into two categories, as seen by the split in the first row in stage 3. The constricted or glottalized vowels were pronounced differently by different groups of speakers, resulting in some groups using a tense voiced (Notated by ‘*’ as used in Korean fortis) vowel and others

² This is a somewhat simplified version of Kingston's account, in which vowel length, the spirantization of certain consonants, and the type of final consonant (stop vs. sonorant/fricative) also affected the tonogenesis process. As there is no indication these traits are at work in Korean, I instead choose to focus on Kingston's overarching idea of how opposite tones formed in the same environments in different languages within the Athabaskan language family.

³ This is a hypothetical, simplified example, used to demonstrate the process.

using a creaky voice vowel. Creaky voice led to a lower tone as speakers left some layers of the vocal folds slack. Tense voice involved the contraction of the higher layers of the vocal fold muscles, which led to phonetically higher vowels. Note that these different voicing qualities did not contrast with each other in the same language, but instead were present in two different dialects. In stage 4, tense or creaky voice naturally cause the pitch to raise or lower. This phonetic cue is heightened until it becomes phonemic, and replaces the initial consonant cue with a tonal contrast. The high or low tone that emerges contrasts with the plain “tak,” which then takes the place of whichever tone is not being used in that language. In this way, Kingston is able to explain how different Athabaskan languages ended up with opposite tonal contrasts in the same environment (Kingston 2005).

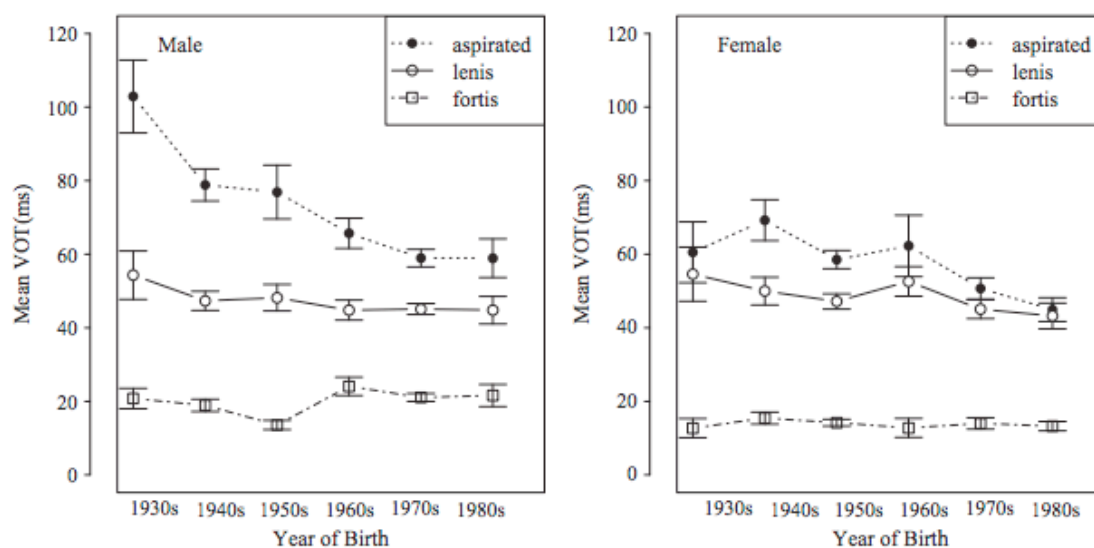
3.2 Korean Consonant Evolution

As mentioned in section 1.2, the lenis consonants have canonically been characterized as having a medium level of aspiration, and the aspirated consonants have been characterized as having a greater amount of aspiration. In recent years however, the aspiration ranges of the lenis and aspirated consonants have begun to overlap, which prompts the question of which consonant’s aspiration level has changed.

Kang (2014) found that aspirated and lenis stops pronounced by Seoul Korean speakers born in 1932 were estimated to differ in VOT by 31.0 ms, while the same stops pronounced by speakers born in 1984 are estimated to differ by only 5.6 ms. The charts

below⁴ in (5) shows the VOT levels of speakers based on year of birth and divided by gender. They provide a picture of how VOT has been changing over the past century; male speakers used to pronounce the aspirated consonant with a much longer VOT. Presumably, female speakers also would show what is a more advanced stage of the change, albeit at an earlier date. Kang also found that female Korean speakers were pronouncing the aspirated and fortis consonants followed with a higher tone before male speakers, demonstrating that female speakers are leading these sound changes in Korean.

(5) VOT by Year of Birth Differences (Kang 2014)



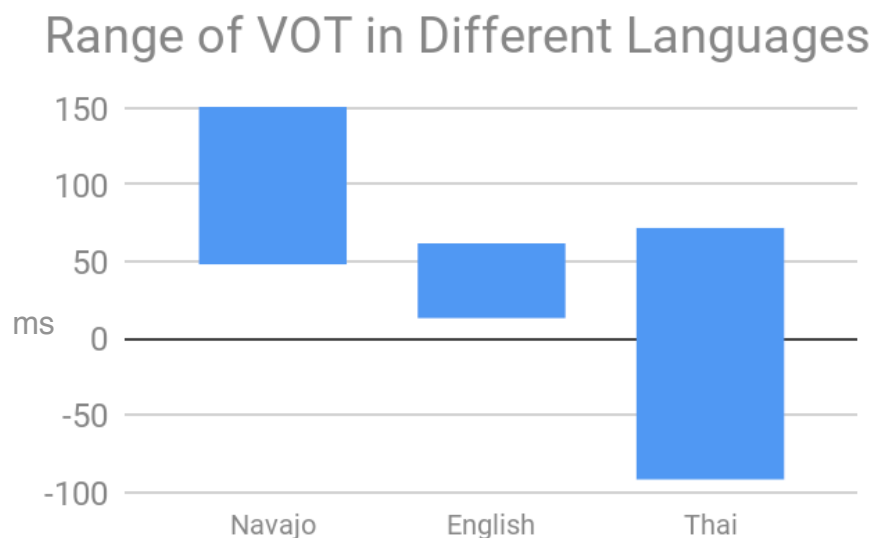
This study does show that the aspirated consonants have become less aspirated over time, and that the aspiration differences between lenis and aspirated consonants

⁴ Reprinted with Permission, Kang 2014. This article was published in *Journal of Phonetics*, 45, Yoonjung Kang, "Voice Onset Time merger and development of tonal contrast in Seoul Korean stops: A corpus study", pages 76-90, Copyright Elsevier (2014).

used to be much greater. I therefore hypothesize that Korean used to have a three-way aspiration contrast, with each of the three consonant types distinguished by aspiration alone. Unlike the present day, where the aspiration range of lenis and aspirated consonants overlap, the data from Kang (2014) supports the idea that historically, the aspirated and lenis consonants had distinct aspiration ranges.

No other language has been found that has a three-way contrast,⁵ however there are languages that support the possibility, given that aspirated consonants have widely different amounts of aspiration across languages. The chart in (6) shows the VOT range between consonants in different languages, with the top of the bar marking the consonant with the longest VOT, and the bottom of the bar marking the consonant with the shortest VOT. As demonstrated in the above example, an aspirated [k^h] in Navajo has around 150ms of aspiration, and a [g] has a VOT of 60ms. Navajo demonstrates that languages can have consonants which contrast based on aspiration, and the VOT range can be quite large. The Thai range encompasses a three-way consonant distinction, demonstrating a possible range for a Korean three-way distinction as well.

⁵ In this circumstance, the distinction between aspiration and VOT is important; there are many languages with a 3 three-way VOT contrast (voiced consonants, voiceless consonants, and aspirated consonants) but no languages with a three-way aspiration contrast (voiceless unaspirated, aspirated, super aspirated).

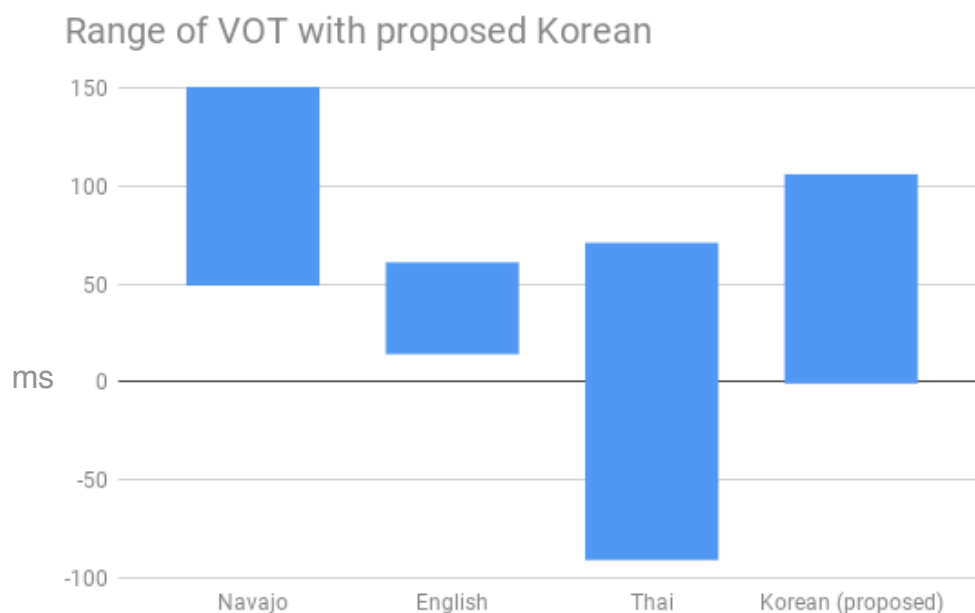
(6) VOT ranges in different languages⁶

In the second chart in (7), the Korean bar is an estimate based on the numbers given by Kang (2014) for male speakers born in the 1930s. The proposed contrast fits into the range of established contrasts and is in no way is an extreme or radical proposal. Therefore it seems plausible that Korean used to have a very aspirated consonant. Navajo has a contrast between aspirated and voiceless consonants (which are realized as aspirated, but with significantly less aspiration than the actual aspirated consonants), and Thai has a VOT distinction between three consonants. It is a plausible proposal that Korean had both of these characteristics; three different types of consonants, all voiceless, all will contrasting VOT ranges.

(7) VOT ranges with Korean range⁷

⁶ Graph is based on a figure and data from Ladefoged and Johnson (2010), page 153.

⁷ Graph (6) (based on Ladefoged and Johnson 2010), with Korean data from Kang (2014).



It seems evident that, overall, the VOT range of lenis consonants has remained relatively the same through the last generations of speakers. Instead, it is the VOT of the aspirated consonants that has lowered and now overlaps with that of the lenis consonants. It is this change that has propelled tonogenesis forward in Korean. As the VOT ranges began to merge, Korean required another way to distinguish the two types of consonants. I hypothesize the aspirated and fortis consonants had a “tense” trait similar to the Athabaskan tense voicing trait, which caused phonetic raising of the pitch of the following vowel. This is similar to the [+stiff] features proposed by Silva (2006), although his proposal was a more abstract way to explain the consonant differences across older and younger speakers, while my proposal does not deal with underlying features. Halle and Stevens (1971) described both the aspirated and fortis consonants as having stiff vocal folds, which supports the idea that both of these consonants have a tense trait. As discussed previously, some Athabaskan languages pronounced

constricted vowels with a tense trait, which ultimately led to the development of a high tone in those environments. Hypothesizing that the aspirated and fortis consonants also have this phonetic trait explains the phonetic high pitched vowels that have developed after both over the last century. These phonetic differences became more pronounced as the lenis and aspirated consonants became more difficult to distinguish due to the overlap of VOT ranges.⁸ As was discussed in section 1.3, Korean is now at a stage where the pitch of the vowel can override the perceptual cues contained in the consonant portion of the word (Kim et al. 2002).

4. Phonetic vs. Phonemic

4.1 Difficulty in determining status of pitch in Korean

Although it is evident that the vowels in Korean are extremely important perceptually, it is difficult to categorically say whether pitch is phonemic or still phonetic. However, a potentially relevant parallel exists in English. It is well known that vowel length is a cue to final stop voicing in English, with longer vowels cueing voiced stops and shorter vowels cueing voiceless stops. For example, the vowel in [kæb], ('cab') is long than the one in [kæp], ('cap')⁹. As in Korean, a property of the vowel is a very strong perceptual cue for a neighboring consonant, only in English the relevant cue is vowel length instead of pitch. English is not considered to have contrastive vowel length, despite the strength of these perceptual cues on the vowel portion of words. The

⁸ There is also some evidence that this tenseness may be present in the pronunciation of [h] as Kang (2014) demonstrates that the [h] consonant is produced with a higher pitched at the beginning of the following vowel.

⁹ This is particularly evident if you whisper the words to yourself.

two languages form a potentially informative parallel in determining whether these perceptual cues are part of phonemic contrasts or phonetic differences in the words. It is possible that pitch in Korean is similar to vowel length in English; simply a phonetic cue for consonant type, instead of forming an actual phonemic contrast. It may be that Korean is developing contrastive pitch (i.e. tone), but to determine the present day status of pitch in Korean, we can investigate the vowel length cues in English. If listeners pay more attention to the perceptual cues in English vowels than in English consonants in the identification of consonants, we will have demonstrated that vowel length in English behaves very similarly to vowel pitch in Korean. This would provide a strong argument that, as English vowel length is not considered phonemic, Korean vowel pitch should fall into the same category, and also be considered phonetic differences rather than phonemic contrasts. To better understand the behavior of vowel length cues in English, I performed an experiment to determine the relative importance of vowel length in perceiving word final consonants. I loosely followed the procedure of Kim et al (2002), who cross-spliced vowel and consonant pairs and asked native speakers to identify the sounds.

4.2 Study of perceptual status of vowel length in English

4.2.1 Participants

Twenty-six native English speakers participated in this perceptual study, seven male and 19 female (Age range: 18-21, Average: 19.5). No participant reported hearing difficulties. No subjects had to be discarded for getting less than 2/3 of the

unmanipulated (matching cues cases) correct (In fact, all participants got at least 93% of the matching cue cases correct).

4.2.2 Stimuli

Audio recordings of words were taken from the Merriam-Webster online dictionary using the software Praat (Boersma and Weenink 2018). Nine different word pairs were recorded; each pair differed only in coda consonants, as in the pair 'cap' and 'cab.' These words were spliced in Praat so that the ending consonants were switched between pairs. This ensured that a voiceless consonant was preceded by a long vowel, and a voiced consonant was preceded by a short vowel. The unspliced word were also included as stimuli to ensure a matching cue case that could be used as a baseline.

4.2.3 Procedure

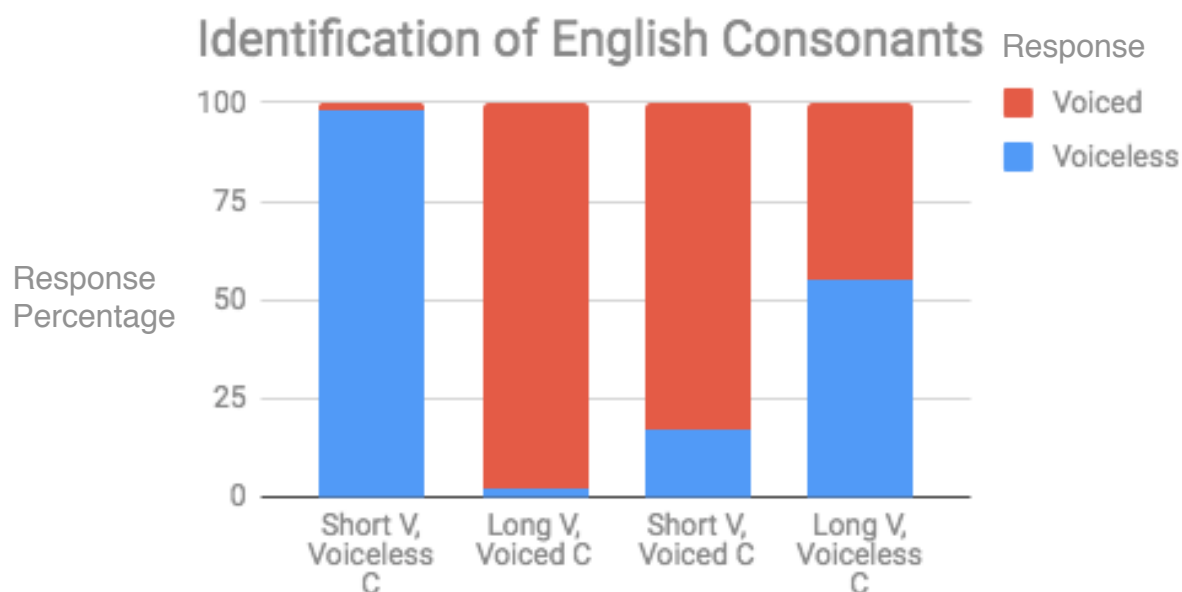
The stimuli were presented in a Multiple Forced Choice task using Praat, with participants listening to each and then clicking the button corresponding to which word they heard. They choose between the voiced and voiceless consonants; for example, choosing either 'cap' or 'cab'. All participants completed the study in a sound attenuated booth using headphones. See stimuli pairs in Appendix.

4.2.4 Results

A logistic regression model was run in SPSS with 'response' (2 levels: voiceless, voiced) as the dependent variable and independent variables 'vowel' (2 levels: long, short) and 'consonant' (voiceless, voiced). 'Subject' was included as a blocking factor.

Post-hoc pairwise comparisons for vowel*consonant were run using Fisher's least significant difference adjustment. All Pairwise comparisons showed a significant difference ($p < 0.001$). The results of the identification task are shown below in (8).

(8) Identification of English Consonant Results



The stimuli with matching cues were identified correctly almost all of the time (the first two columns); unsurprising, as these stimuli were normal English words. As seen in the third column, when short vowels were followed by voiced consonants, the mismatching cues cause some confusion for the listeners, and these were identified as ending in voiceless consonants 17.2% percent of the time. It seems that, in this case, listeners were somewhat confused by the conflicting cues, and, while normally basing their choices on the consonant cues, would occasionally instead choose based on the vowel cues. When long vowels were followed by voiceless consonants, participants were split; 55% identified the word as ending in a voiceless consonant, and 45%

percent as voiced. Thus we see that in some cases, the vowel based cues were strong enough to override the cues in the consonant portion of the word.

4.3 Implications of English study for Korean pitch contrast

Similarly to Korean, English contains important perceptual consonantal information on the vowel portion of words, which makes it a good parallel case to English. In Korean, this information seems to be the pitch of the vowel; in English, it is the vowel length. In both languages, these vowel-based cues can override the perception of those in the actual consonant portion of the vowel, though they do not always do so, depending on the vowel and consonant combination (Kim et al 2002, Henshaw and Lunden 2017). Although, as mentioned, it is possible for the vowel cues to override the consonant cues in English, English speakers still base their identification of consonants off of the cues in the consonant portions the majority of the time. In Korean however, the vowel cues seem to be perceptually stronger; in Kim et al's experiment, listeners were found to base their identification off of vowel cues 87%¹⁰ of the time when lenis vowel portions were present. We are specifically looking at stimuli where the lenis portions were present as the lenis consonant is the only one followed by a vowel with low pitch. When the vowel portions are switched between the fortis and aspirated consonants, it does not give us useful information as the vowel portions are too similar to each other due to their mutual high pitches. Korean speakers identify consonants as lenis based on the vowel portion the vast majority of the time. While vowel length is sometimes marked in transcriptions of English, it is clearly a phonetic

¹⁰ This number is the average of responses for the stimuli comprised of fortis consonants followed by a "lenis" vowels and the stimuli comprised of aspirated consonants followed by "lenis" vowels.

cue used in consonant identification, rather than a phonemic contrast (Ladefoged and Johnson 2010). However, it is not entirely clear where pitch in Korean lies on the phonetic to phonemic scale. As lenis vowel cues override consonant cues the majority of the time, it seems likely that vowel pitch in Korean is closer to being a phonemic contrast rather than a phonetic cue. It is difficult to determine when a cue becomes a phonemic contrast in many cases however. Tonogenesis is a process, and while it may be useful to divide it into stages, in reality it can be difficult to draw the lines to determine when a language should be classified as fully tonal. In comparison to Kingston's Athabaskan model, Korean appears to be between stage 3 and 4, as the pitch differences are emerging but it is unclear if these differences are now a phonemic contrast. In Maran's (1973) account of tonogenesis, Korean appears to be between stage 4 and 5; the VOT ranges are overlapping, but it is not clear that they have entirely merged.

There is a potential priming factor difference between the English study I performed and the study done by Kim et al. however. In Kim et al's study, participants heard the target consonant first, then a following vowel with cues that did or did not match this consonant. In the English experiment, this order was reversed, with the vowel being heard first followed by the target consonant. The stimuli were created in this fashion due to the fact that the syllable-final consonants in English influence the preceding vowel, not the following. Participants heard the vowel and the corresponding vowel cues first in the English study, which could have primed them to identify the consonant a certain way. However, even if this priming factor did influence the outcome of the study, the English study found that listeners relied on consonant cues over vowel

cues the majority of the time, no matter which conflicting cues were present. If the priming factor influenced the study, it was not to a large degree, as the participants always relied on consonant cues to identify the consonant.

5. Conclusion

The contrast between lenis and aspirated consonants is emerging as a pitch difference on the following vowel. Kim et al. (2002) demonstrated that perceptual cues on the vowel portion of Korean words can override the cues on the consonant portions, so that listeners identify the consonant spoken based on the vowel cues present.

Kingston's 2005 paper gives a historical account of tonogenesis in the Athabaskan language family, providing an interesting example with which to compare Korean. As in Maran's (1973) account of tonogenesis, Athabaskan languages were proposed to have started with a specific consonant contrast; in this case, glottalic and nonglottalic consonants. The vowels near the glottalic consonants became coarticulated with the consonants, gaining a constricted voice quality. As time progressed, the consonants lost their contrasts, but the vowels retained the constricted voicing quality. In some languages, speakers pronounced this constriction with a tenser property, leading to tense voicing. The tense voice naturally raised the pitch of the vowel; overtime this led to vowels with normal voicing and high pitch. In the other languages, creaky voice naturally lowered the pitch of the vowel. Over time, the voicing quality was lost and the lower pitch became phonemic. In this way, Kingston gives an account of how differing pitch contrasts occur in the same environment in different Athabaskan languages.

Investigating the recent evolution of Korean consonants has provided us with insight into how the tonogenesis process has been occurring in Korean during the last century. I proposed that Korean's unique three-way contrasting consonants once contrasted solely based on aspiration; this is consistent with the rates of aspiration from speakers of different ages given in Kang (2014). From Kang (2014), we know that over the last century, speakers have begun to pronounce the aspirated consonants with less and less aspiration; so much so that the aspiration range of these consonants now overlaps with the aspiration range of lenis consonants for many speakers. While this change was occurring, speakers began to need another way to distinguish aspirated and lenis consonants. To solve this problem, they enhanced the pitch differences of the vowels following the aspirated consonants. The fortis consonants have an underlying tense property; as seen in Kingston's account of Athabaskan languages, this naturally raises the pitch of the vowel as well. While classically aspirated consonants are considered the aspirated version of the plain (lenis) consonants, they may be better thought of as an aspirated version of the fortis consonant, as these two consonant types both possess a tense quality which has caused phonetic raising of the vowel pitch. This is how today we ended up with high pitched vowels following fortis and aspirated consonants and lower, or normal, pitched vowels following lenis consonants.

In an attempt to assess the emergence of a phonemic contrast in Korean, I ran a perceptual experiment investigating the relative perceptual importance of the preceding vowel length on the voicing of English stops. It was found that, while vowel length can be a contributing factor to the perception of voicing in English consonants, English speakers still heavily base their identification of consonants on the cues in the

consonant portions of words. On the other hand, Kim et al. found that Korean speakers rely much more on the the lenis vowel portions to identify the consonant stimuli than they did the consonant portion. It is therefore clear that the vowel portions in Korean hold much stronger perceptual cues than those of English, which demonstrates that it would insufficient to label the pitch difference of Korean vowels as simply a phonetic cue. Instead, Korean appears to be much closer to gaining a phonemic vowel pitch contrast. Korean appears to be in the later stage of tonogenesis when compared with other accounts; between stages 3 and 4 when compared with Kingston's Athabaskan account, and between stages 4 and 5 when compared to Maran's account.

The hypothesis has been put forward that historically Korean has moved from a three-way aspiration contrast to a more common two-way aspiration contrast, leaving the lenis and aspirated consonants essentially indistinguishable. In turn, this has led to the enhancement of the phonetic pitch differences from what is assumed to be the inherent vocal fold stiffness associated with aspirated and fortis consonants. While the pitch differences of the vowels in Korean are of great perceptual importance, it is not clear that they have developed into a phonemic contrast, nor is it clear that the lenis and aspirated consonants have ceased to contrast entirely outside of these pitch differences. Therefore Korean is in a very late stage of tonogenesis, and is likely to become fully tonal in coming years as the lenis and aspirated consonants become entirely indistinguishable and the pitch differences of the vowels become a robust phonemic contrast.

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Appendix

Stimuli pairs used in English experiment reported on in section 4.2

Stimuli Pairs

Ending in voiceless consonant	Ending in voiced consonant
Cap [kæp]	Cab [kæb]
Cop [kɒp]	Cob [kɒb]
Dock [dɒk]	Dog [dɒg]
Jock [tʃɒk]	Jog [tʃɒg]
Lock [lɒk]	Log [lɒg]
Mop [mɒp]	Mob [mɒb]
Not [nɒt]	Nod [nɒd]
Pat [pæt]	Pad [pæd]
Pot [pɒt]	Pod [pɒd]
Rot [rɒt]	Rod [rɒd]
Tack [tæk]	Tag [tæg]