‘PLACELESS’ CONSONANTS IN JAPANESE: AN ULTRASOUND INVESTIGATION

by

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ABSTRACT

This dissertation investigates the place of articulation of allegedly 'placeless' consonants of Japanese - the moraic nasal /N/ and the glottal fricative /h/. In the discipline of phonology, these two consonants have typically been analyzed as having no place features of their own, on the grounds that their place features are predictable from the adjacent segments, that they often appear as outputs of debuccalization, and that they show high articulatory variability.

While some researchers believe that certain segments are placeless both phonologically and phonetically, it has not been examined how these Japanese consonants appear in the surface phonetics. The current research instrumentally tests the hypothesis that they have articulatory targets, based on qualitative and quantitative examination of data produced by native speakers of Japanese. Such a study is important in order to fill the scientific gap between the phonological theories and phonetic approaches to the study of sounds.

Ultrasound experiments were conducted on six native speakers of Tokyo Japanese, and the tongue movement was analyzed. The tracing of the overall tongue configurations on the ultrasound imaging was done by EdgeTrak (Stone 2005). The data for placeless segments were compared to those for the adjacent vowels, in terms of tongue shape, constriction degree and constriction location.

The results involve three significant points: First, /N/ shows a significant dorsum raising for all speakers, while /h/ shows a pharyngeal constriction for 5 out of 6 speakers. Second, the constriction location is different across speakers: The location of /N/ ranges from post-alveolar to uvular, and the location of /h/ is either uvular or pharyngeal. Third, /N/ and /h/ had no more variability than /k/, which is widely assumed to be a velar-specified segment.

This research empirically confirms that these two segments are articulatorily stable within a speaker but variable across speakers. This contradicts long-standing views about the segments in question. The individual variability may also lend support for the phonologization of different phonetic interpretations. Finally, the place-features of these same segments could be different across languages, and further instrumental studies of these sounds are encouraged.

PREFACE

Certain preliminary results from this dissertation research have been presented previously in:

- Yamane, Noriko, Bryan Gick, and Douglas Pulleyblank (2011) "Pharyngeal /h/ in Japanese," *Canadian Acoustics*, Vol. 39, No. 3. 174-175.
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AVG	average
C	consonant
C-pl	consonant-place
CD	constriction degree
CL	constriction location
IPA	International Phonetic Alphabet
IQR	interquartile range
Phar	pharyngeal node
PoA	place of articulation
SD	standard deviation
SPE	Sound Pattern of English (Chomsky and Halle 1968)
SS-ANOVA	smoothing spline ANOVA
TI model	target and interpolation model (Cohn 1990)
Uvul	uvular
V	vowel
Vel	velar
V-pl	vowel-place

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Chapter 1 **Introduction**

This dissertation is a multiple case study of Tokyo Japanese, with an aim to examine phonetic and phonological variations of certain sounds of Japanese. Japanese is rich in dialects, and I will occasionally bring some of these other dialects into the discussion when it is relevant. The variations that are instrumentally examined in this dissertation are interspeaker variations within Tokyo Japanese. The term Tokyo Japanese here means equivalent to the 'standard' Japanese (or 'hyoojun-go') which has been developed over the past 100 years, and which is currently attested also in the western Kanto areas such as Kanagawa, Saitama and Chiba prefectures.

The sounds that I explore in this dissertation are two kinds of allegedly placeless consonants: One is the so-called placeless nasal, denoted as N, and the other is the glottal fricative /h/. The distinction between these two consonants may be made in terms of the division of underlying and surface representations or input and output of phonology. Thus, /N/ is considered as underlyingly placeless (i.e., the surface place is phonologically received from adjacent segments), and /h/ as permanently placeless (i.e., the surface place is phonetically interpolated). However, there is disagreement about the boundary between phonetics and phonology as well as how placelessness is defined. This dissertation aims to clarify the distinction of phonetics and phonology, and give placelessness a measurable definition.

One key concept that I use in exploring these questions is that of target. A target is a goal which human beings aim to achieve when conducting a task. Based on the idea that speech production is a motor act of articulation, speech may be thought of as consisting of articulatory gestures which have targets, the achievement of which can be modeled using a dynamical systems approach (Kelso, Saltzman & Tuller 1986). Browman & Goldstein (1986) follow Kelso et al. (1986), and apply the "task-dynamic" model to phonology, where vocal tract locations such as the lips and tongue body have a target when performing the task of making a constriction.

The target of one allegedly placeless segment – the schwa of American English - has been experimentally explored in Browman & Goldstein (1992), and the acoustic results suggest that this schwa has a target. Gick's (2002b) x-ray investigation also shows more clearly the pharyngeal constriction for schwa. However, in many other generative phonological frameworks, schwa has been assumed to be placeless, as it is assumed to be articulatorily in a neutral position in the oral cavity, and it shows up as an epenthetic vowel in weak positions. From such a viewpoint, the existence of a discrete physical target for schwa is surprising, as it is against the general belief that schwa has no place feature. The finding poses a further question as to how the phonological place feature and the phonetic place target are related, and what kinds of segments lack a place target.

In order to answer these questions, the relation between "targets" and "place" needs to be clarified. It is safe to say that it is a subset relation as given below.

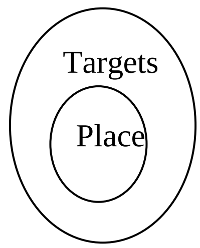


Figure 1.1. The place-target relationship

One of the notable differences is that targets exist for a wider range of vocal tract locations, which include the Larynx, Oral cavity (henceforth 'Oral') and Velum.[1] For example, speakers can round or flatten their lips, which contrasts rounded vs. unrounded segments. The glottis can be closed, open or narrow to create a glottal stop, voiceless, or voiced sound. The tongue root can be retracted toward the wall of the pharynx, which may differentiate pharyngeal sounds from oral sounds; the velum can be lowered, which would differentiate oral sounds from nasal sounds. As well, the degree of constriction is adjustable, so that stops and fricatives can be differentiated. The vibration of the vocal folds can be fast or slow, so that high and low tones can be created. Thus there are various types of targets, and it is reasonable to say that place, which exists in the oral tract, is just one part of these targets. The definitions of target and targetless that I will be using in this dissertation are given below.

- Target is a vocal tract configuration or an auditory effect which a speaker aims to form when producing a sound.
- Targetless is a vocal tract configuration or an auditory effect which has no target.

[1] These are capitalized because they are nodes in vocal tract locations.

In other words, targets exist in all vocal tract locations. "Place" as I refer to it in this dissertation is a property that belongs to Oral. In this model, Oral consists of Lips, Tongue Tip, Tongue Body and Tongue Root. In generative phonology, these are referred to as Labial, Coronal, Dorsal, and Pharyngeal respectively.

This chapter is organized as follows. Section 1.1. lays out the theoretical background. Section 1.2. reviews the moraic nasal of Japanese. Section 1.3. reviews the glottal fricative of Japanese, Section 1.4. shows a roadmap of the dissertation.

1.1. Background of Placelessness

Researchers' conception of the relation between phonetics and phonology is not uniform, but clarifying this relation is critical for my research on phonological place and phonetic place.

The focus of this section is laid on the interface issue – how the difference between phonetic place and phonological place has been treated in various influential theories. It will be found that theories make different predictions about i) how the correspondence between the two works, and ii) whether there may be a phonetics-phonology mismatch, and if there is, whether it would be a problem for the mapping.

1.1.1. Trigo (1988)

Trigo (1988) claims that crosslinguistically there are "glide-like transitional elements similar to Sanskrit <u>anusvara</u>" (ibid. 25) (underline original) or "place-less nasal glide[s]" (ibid. 32), and represents this as [N]. According to Trigo, such a segment "lacks an oral point of articulation" (ibid. 20) and "lack[s] a place component" (ibid. 20-21). Phonologically, (i) [ŋ] tends to alternate with [N], and (ii) nasalized vowels alternate with [ṼN]. She raises examples from Japanese, Malay, Choctaw, Terengganu, Murul, Uradhi, Polish, Chukchi, Spanish dialects, etc. I will introduce some of her Japanese examples, and show how she argues that Japanese /N/ is phonologically placeless, and how it is realized phonetically.

Trigo illustrates the phonological alternation between placeless and velar by using a feature geometry, where a Place node, a Stricture node including [consonantal] and a Soft Place node are under the Supralaryngeal node. Her crucial assumptions are given below.

(1.1) Relation between [consonantal] and place (Trigo 1988: 11)

a. A segment with no place features is [-consonantal].

b. A [+consonantal] segment cannot remain placeless.

Trigo adopts Chomsky & Halle's (1968: 303) feature system where [h, ʔ] are [-consonantal], and categorizes these segments as placeless glides.

Trigo pays attention to Japanese N's inability to trigger epenthesis, and argues that it is a placeless glide. The examples below are from the foreign vocabulary of Japanese (i.e., loanwords).[2]

(1.2) Inability of /N/ to trigger epenthesis in the foreign vocabulary (Trigo 1988: 33)

a	waʃintoN	'Washington'
b	ʃimputom<u>u</u>	'symptom'
c	koot<u>o</u>	'coat'

In Trigo's generalization, epenthesis occurs only after true consonants – segments having [+consonantal] such as [r, t, g, k, ts]. But epenthesis does not occur after /N/ (e.g., *waʃintoNu, *waʃintoNo). It follows that /N/ is [-consonantal].

The inability to trigger epenthesis is not limited to the foreign vocabulary, but is observed in the Sino-Japanese vocabulary as well.

(1.3) Inability of /N/ to trigger epenthesis in the Sino-Japanese vocabulary (Trigo 1988: 34)

a.	dai-gak<u>u</u>	/dai-gak/	'university'
b.	gak<u>u</u>-bats<u>u</u>	/gak-bat/	'academic clique'
c.	gak<u>u</u>-moN	/gak-moN/	'learning'

The default vowel in Sino-Japanese is /u/, with backness harmony across /k, t/ (see Tateishi 1990, Itô & Mester 1996, Kurisu to appear for further details). Again Trigo attributes the

[2] The epenthetic vowel quality is different depending on the lexical stratum - /i/ in the native vocabulary, and /u/ in the foreign vocabulary, but /o/ appears after /t, d/ (Poser 1984a, b, Itô 1986).

asymmetry between [k, t] vs. [N] to the value of [consonantal]. [N] has to be [-consonantal] unlike [k, t].

The second argument that Japanese /N/ is a placeless nasal is from Kagoshima Japanese.

(1.4) Debuccalization in Kagoshima Japanese (Trigo 1988: 34-5, based on Haraguchi 1984)[3]

(i) nouns

a.	obi	→	ob	→	oʔ	'belt'
b.	matu	→	mat	→	maʔ	'pine tree'
c.	doku	→	dok	→	doʔ	'poison'
d.	kagi	→	kag	→	kaʔ	'key'
e.	hidzi	→	hidz	→	hiʔ	'elbow'
f.	kami	→	kam	→	kaN	'god'
g.	inu	→	in	→	iN	'dog'
h.	tuyu	→	tuyu	→	tuyu	'dew'
i.	kasu	→	kas	→	kasu	'draft'
j.	kizi	→	kiz	→	kizi	'bell'

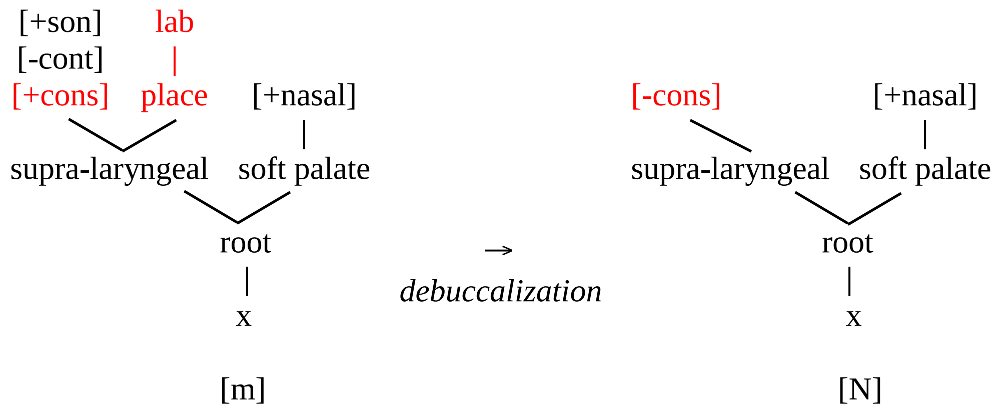
(ii) verbs

a.	oku	→	ok	→	oʔ	'to put'
b.	katu	→	kat	→	kaʔ	'to win'
c.	karu	→	kar	→	kaʔ	'to cut'
d.	umu	→	um	→	uN	'to give birth'
e.	osu	→	osu	→	osu	'to push'

Trigo postulates that i) high vowel deletion in word final position and ii) debuccalization of the final consonant (i.e., [ʔ] if oral, and [N] if nasal) apply in that order. She assumes that place features are properties of [+consonantal], proposing the debuccalization rule as "place → 0 /_#", as represented below.

[3] See Kaneko & Kawahara (2002) for its OT analysis.

(1.5) Debuccalization to /N/ (Trigo 1988: 12)



As in the lefthand side, debuccalization is expressed through the deletion of the place node. Trigo assumes that there is a subsequent gliding process which shifts [+cons] to [-cons] in Japanese. The evidence is the inability to trigger epenthesis, and she assumes that all surfacing (or derived) glides are [-consonantal].

However, /N/ is often velarized, and the question to ask is why it has to be velarized. Trigo presents the hypothesis below.

(1.6) Velarization as interpretation of placeless [+consonantal] segments (Trigo 1988: 48)

Velarization occurs when a placeless segment becomes [+consonantal] so that the need arises to interpret that [+consonantal] feature.

Thus after the debuccalization, the debuccalized segment has two options available. One is to remain [-consonantal] to keep /N/ as in the hypothesis above, and the other is to become [+consonantal] to become velarized. The question is whether all cases of placeless segments have to be velarized. Trigo (1988: 45) says "[t]his process is manifested in <u>languages lacking phonemic [N, h] or [ʔ]</u> [emphasis N.Y.]." Trigo (1988: 51) also states:

> If we assume that velarization can be a means of licensing the [+consonantal] feature of a place-less consonant, we can predict that velarization will occur whenever a place-less glide is created <u>which is not present in the underlying inventory of the language in question</u> and is consequently reanalyzed as a [+consonantal] segment. [emphasis N.Y.]

That is, if /N/ is not in the underlying inventory, /N/ is predicted to shift to velar, while if it is in the inventory, it remains placeless. Interestingly, Trigo (1988: ch.2) argues that the phonological rule that inserts dorsal place applies to placeless consonants generally - /ʔ, h/ as well as N. It follows that Japanese N, which is in the phoneme inventory (e.g., as a uvular nasal in Kubozono & Ota 1998), remains placeless at surface. It does not have to get velarized.

The feature system below is the one Trigo proposes in order to show the similarity of velar segments and glottal segments. It is suggested that velar /k, x/ appear as the phonetic realization of the placeless [+consonantal] segments /ʔ, h/ if they are not in the inventory.

(1.7) [consonantal] distinction between velars and glottals (Trigo 1988: 49)

p f	t s	k x	ʔ h	
+	-	-	-	anterior
-	+	-	-	coronal
+	+	$\boxed{+}$	$\boxed{-}$	consonantal

Trigo (1988: 49) states "On this view [h ʔ N] acquire a (predictably) velar point of articulation by being interpreted as consonants."

Trigo proposes two possible mechanisms of velarization. One is assimilation to the adjacent vowel as in (1.8a), and the other is the insertion of [+back, dors] as in (1.8b).

(1.8) Velarization as either assimilation or insertion (Trigo 1988: 55-6)

a. assimilation

[αback]			[αback]	
dors		→	dors	dors
sl	sl-[+cons]		sl	sl-[+cons]
V	ʔ		V	k

b. insertion

[αback]			[αback]	[+back]
|			|	|
dors		→	dors	dors
|			|	|
sl	sl-[+cons]		sl	sl-[+cons]
V	ʔ		V	k

(sl: Supralaryngeal node, dors: Dorsal, [+cons]: [+consonantal])

First, debuccalization deletes the place feature from the consonant, leaving [+cons] behind. Then in order to interpret the [+cons] segment, place is acquired either via assimilation to the adjacent segment as in (a), or via the insertion of [+back, dors] as in (b). The assimilation option predicts a placeless consonant becomes velar after a back vowel and palatal after a front vowel. On the other hand, the insertion option predicts the place consonant always becomes velar. Trigo adopts the insertion analysis for the sake of simplicity. She states that the latter analysis predicts [+consonantal] glottals must acquire a point of articulation to implement [+consonantal], while [-consonantal] glottals do not need to do so and will surface as such. This statement is summarized below.

(1.9) Two kinds of surface forms based on Trigo (1988)

	system A	system B	
underlying	/m, n, ŋ, N/	/m, n, ŋ/	phonology
debuccalization	N[+cons]	N[+cons]	
gliding	N[-cons]	—	
velarization	—	[ŋ]	phonetics
surface	placeless [N]	velar [ŋ]	

Whether the nasal segment in question is placeless or not on the surface depends on the phoneme inventory. If /N/ is phonemic as in system A, then placeless /N/ has no reason to have [+cons] during the derivation, so it remains placeless. But if debuccalization creates a sound that is not in the inventory as in system B, then /N/ retains [+cons] and the [+cons] of placeless /N/ is interpreted as the velar [ŋ].

1.1.2. Keating and Cohn

There are two major schools of laboratory phonology that examine the relation between the physical objects/signals of phonetics and the abstract symbolic features of phonology. One is Generative Phonetics, which takes language specific phonetics seriously into account for phonology (Keating 1988, 1990, Cohn 1990, 1993, Kingston & Diehl 1994, Beckman & Pierrehumbert 1986, Pierrehumbert 1990). Pierrehumbert (1990: 391) claims that the phonetic realization is not just automatic or universal, because the phonetic interpretation of categories differs from language to language. The other school is Articulatory Phonology (Browman & Goldstein 1986 et seq., Goldstein & Fowler 2003). They propose that the gesture is the unit of phonology rather than the feature. Both schools share the idea that gradient aspects of physical signals tell us significant things about phonological structures.

The relevant point here is their hypotheses about how featural specification should appear in physical signals. Here I will explain the prediction of Keating (1988, 1996) and Cohn's (1990) Target and Interpolation Model (henceforth the TI model) that I will adopt in the subsequent chapters.

Taking examples from English, Farsi and Swedish, Keating (1988) argues that the oral features of intervocalic [h] remain unspecified at the surface phonetics. The evidence is the shape of the second formant: In contrast to the discrete pattern of regular segments such as [b], the intervocalic [h] is transitional between the two vowels and interpolated.

Also, Cohn (1990) argues that the featural specification depends on the lexical contrasts of the language. For example, vowels may be specified in the phonology as [+nasal] or [-nasal] in French, but vowels in English may remain unspecified for nasality into the phonetics. Her nasal flow experiment shows that discrete patterns were found for French vowels, while gradient patterns were found for English vowels. As predicted, the gradient/cline patterns were found for unspecified features; the results of her experimental work support the idea that the featural specifications of phonological output representations and the physical realizations have a close connection.

Different models make somewhat different predictions about what we expect to see in featurally-unspecified segments.[4] In the TI model, every segment has inherent duration and has ranges of permitted values, not single spatial points. These different ranges of permitted values are represented with a window width: If the segment has a precise target, it has a narrow window, thus there should be little variation across contexts. On the other hand, if the segment is targetless, it has a wide window, thus much variation across contexts is expected. Keating (1996: 273) states,

> The diagnostic for phonetic underspecification, then, is variability across contexts. If there is no phonetic specification, then what you see will depend entirely on the surrounding specifications, which will trigger interpolation through the unspecified span in a temporally-gradient fashion.

It may seem that Cohn (1990) and Keating (1996) capture unspecified patterns with different concepts: Gradiency/clines for Cohn, and variation for Keating. But both concepts are in a direct relationship. For the cline type to show up, the window has to be wide, and if the window is wide then the cline type can show up.

The interpolated signals of an unspecified feature show up as a cline type in a wide window, especially when flanked by segments whose featural values are opposite. See Figure 1.2. for the example of [nid] 'need' in English.

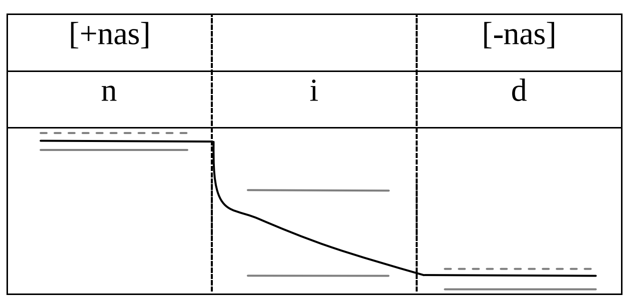


Figure 1.2. Nasal flow in [nid] 'need' in English (adapted from Cohn (1990: 148))

[4] The prediction of Articulatory Phonology is somewhat different from that of Target Interpolation. Articulatory Phonology predicts two vocalic gestures (Tongue Body [pharyngeal, wide]) partly overlap the consonantal gesture (Velum [open]), and the intermediate point in tongue body position of /N/ is expected to be closer to a rest position. This is because "[w]hen a given articulator is not involved in any specified gesture, it is attracted to a 'neutral' position specific to that articulator ..." (B&G 1989: 214). Thanks to Alexei Kochetov for pointing this out.

Each box represents the time span of the segments, and the horizontal pairs of lines in the box are the permitted range, or "window" in Keating's term, of the amount of nasal flow for the segment. As the illustration shows, the targeted segments are marked with the extreme contrastive configurations - widening and closing of the velum. The intervening vowel, on the other hand, has a wide window because it lacks specification of nasality. If it has [-nas], the instantiation of nasal flow should not be different from that of [d]. But what it actually shows is the interpolative quality. Thus, targetlessness, in general, can be attested in the gradual interpolative quality in the wide window.

This stands in a sharp contrast with the signal of a specified target. The following example is French *Leon* [leɔ̃] /leɔ̃/ 'Leon'. French has a lexical contrast between nasal vowels and oral vowels, and in this case, the vowel [ɔ̃] has a target for [+nas]. Every segment here has a specified target ([-nas] for [le], [+nas] for [ɔ̃]), thus has only a narrow window, where the nasal flow appears with a stable discrete flat line or plateau shape.

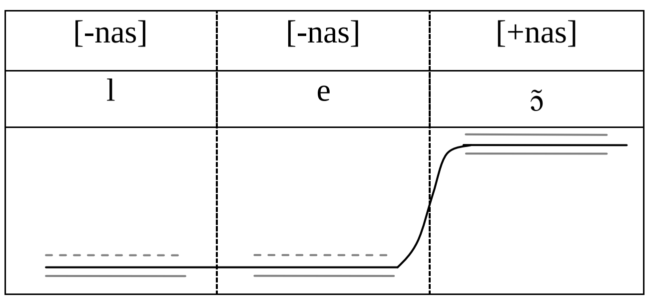


Figure 1.3. Nasal flow in French *Leon* [leɔ̃] /leɔ̃/ 'Leon' (adapted from Cohn (1990: 101))

Keating and Cohn's stance is different from that of classical generative phonology, as reflected in *The Sound Pattern of English* (hereafter SPE; Chomsky & Halle 1968), which assumes that universal phonetic rules automatically turn abstract phonological surface representations into physical signals, and that the mapping is uniform across languages. Cohn (1990) argues that language-specific rules should be introduced into the model, since "nasalized vowels" correspond to different shapes of signals, depending on whether the nasality is contrastive for vowels in the language. French phonemic nasalized vowels show a discrete target, but English nasalized vowels show an interpolation pattern. One important implication is that an “allophonic nasalization” rule/process does not even exist in the phonology of English, and the attested pattern should be treated in the language-specific phonetics.

1.1.3. De Lacy

Since the advent of Optimality Theory (Prince & Smolensky 1993; hereafter OT), phonological asymmetries attested in phonological alternations and segment inventories have been analyzed in a constraint-based system where faithfulness constraints and markedness constraints interact with each other. One of the most important proposals is that markedness has been directly embodied in the universal markedness constraints, whose ranking is universally fixed. However, as for the markedness constraints on Place of Articulation (hereafter PoA), what the universal markedness constraints are and how they are ranked are slightly different in the literature.

What is problematic with respect to Japanese placeless consonants is the lowest end of the PoA hierarchy, which denotes the least marked place. For example, Prince & Smolensky (1993) proposes that the lowest end of the PoA hierarchy is Coronal, while Lombardi (1995, 1998) argues that it is Pharyngeal. De Lacy’s theory (2002a, b, 2006, 2007a, b, 2009, 2010) puts Glottal as the least marked place. But what is unique about this category is what he calls “non-placeless glottal” segments. These segments, including [ʔ, h, ɦ, N], used to be represented with no place node in a representational approach (e.g., Steriade 1987b, Avery & Rice 1989b), showing the unmarked nature of the glottals. However, De Lacy (2006: sec. 8.4) argues that markedness should not be treated as representational complexity, but should be treated with a formal theory of markedness.

The focus here is on the composite segments of “non-placeless glottal”. De Lacy (2006: 37ff.) argues that there are two kinds of glottal nasals – i) [ɦ̃] or “nasalized glottal continuant”, equivalent to what Trigo calls anusvara (see sec. 1.1.1.), and ii) [N] “glottal nasal stop” or “nasalized glottal stop”. De Lacy states that the former is attested in word-final codas in “many Japanese dialects”, and refers to McCawley’s (1968: 84) description of Japanese [ɦ̃] as “a nasalized prolongation of the preceding vowel”. He raises the word-final nasal in Kagoshima Japanese as an example for the “glottal nasal stop” [N].

In de Lacy's phonological system, /N/ is glottal; however, he states that it is phonetically velar or uvular. As phonological evidence for the claim that /N/ is glottal especially for Japanese, he introduces the debuccalization of Kagoshima Japanese (e.g., obi → ob → oʔ 'belt', kami → kam → kaN 'god' (Haraguchi 1984, Trigo 1988: 34, Kaneko & Kawahara 2002). He does not explicitly say that this non-placeless glottal view holds true in Tokyo Japanese as well, and it is not clear either what he thinks about the dialectal difference. But the /N/ of Tokyo Japanese can also be taken as a case of what he calls glottal nasal stop [N], because a similar debuccalization to /N/ is attested in Tokyo Japanese (see 1.2.1.2.). In the usual sense, glottal implies no constriction anywhere in the oral cavity. But de Lacy gives a special note, stating that constriction does occur around the velum as a side effect during the production of the glottal nasal. Since the velar constriction is a side effect coming from velum lowering, it should not happen to the glottal oral stop [ʔ] and glottal fricative [h]. So unlike [ʔ, h], [N] may become velar at the phonetic level.[5]

The consequence of this assumption is that one phonetic place - velar - corresponds to two phonological places – dorsal and glottal - as below:

(1.10) Phonetic neutralization to velar nasal (de Lacy 2006, 2009)

output of phonology	[ŋ]	[N]
output of phonetics	[ŋ]	

The question is whether and how we could distinguish them phonetically. De Lacy (2006: 37-8) argues that [N] actually has no exact target like velar. He continues,

> In short, a nasal stop phonologically specified as [glottal] is not articulatorily impossible given the revised interpretation of [glottal]. In practical terms, this proposal means that the two phonologically distinct segments [ŋ] and [N] have a similar phonetic realization, but for quite different reasons. The phonological specifications of [ŋ] issue a directive for velar constriction; in contrast, the phonological specifications of [N] merely require a direct route from source to

[5] This velar PoA in the phonetics does not have to be velar in the narrow sense, but the constriction arising from the velum lowering could be velar or uvular, perhaps depending on the vowel context. Uemura (1997a) takes a similar position (see sec. 1.2.2.1.), and assumes that the place of /N/ changes depending on the backness of the vowel. It may be sufficient to say 'dorsal'.

radiation point, and velar constriction happens to be necessary to achieve this goal. Because no exact target for [N]'s occlusion is specified, it is possible that it may vary between velar and uvular. As the focus here is on phonology, identifying the degree of variation in the phonetic realization of [N] will be left to future work. (de Lacy 2006: 38-9 [emphasis N.Y.])

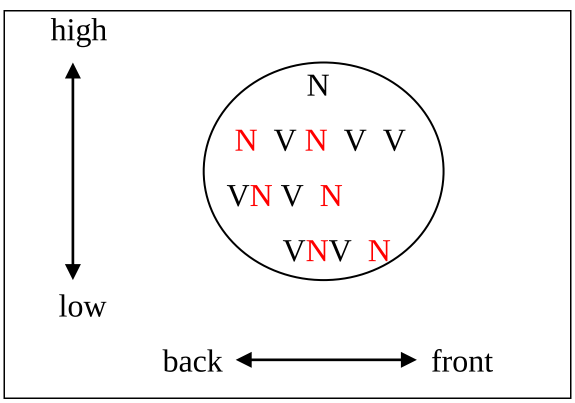
In this way, he insists that [N] is phonologically glottal, but phonetically lacks an exact target location and is realized at the velar-uvular region. Thus the difference can be seen as below:

(1.11) Phonetic difference between [ŋ] and [N]

output of phonology	[ŋ]	[N]
output of phonetics	[ŋ]	[ŋ~ɴ]

The view of /N/ as non-placeless glottal is testable in comparison with other views. Below I will introduce diagrams of the constriction points of this sound in the oral tract [6] to explain what is unique about this view. For clarification, de Lacy's view will be compared with the view of /N/ as placeless glottal, the view of /N/ as velar, and the view of /N/ as uvular. The sketch shows the space of the oral cavity facing to the right. The horizontal dimension signifies tongue backness; the left-hand side is the tongue root and the right-hand side is the tongue tip. The vertical dimension signifies tongue height. The positions of the symbols 'N, V, k' denote the constriction positions of a moraic nasal, a vowel, and a voiceless velar stop respectively.

(1.12) Placeless view (No oral constriction target)



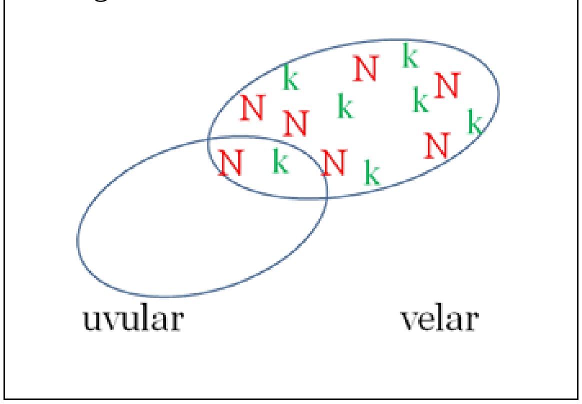
[6] Thanks to Douglas Pulleyblank for sharing the idea of the diagrams and the discussion with me.

In the Placeless view, the overall distribution of the constriction point of /N/ should overlap with those of the adjacent vowel. Constriction Degree (henceforth CD) and Constriction Location (henceforth CL) should be roughly the same.

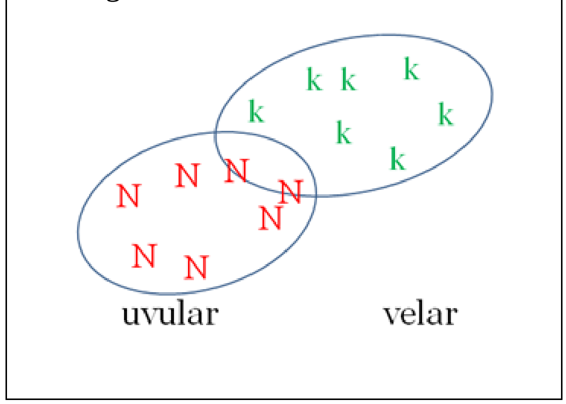
The place views that I demonstrate here are (a) velar and (b) uvular. The difference should be visible if the point of articulation of /N/ and those of /k/ are compared.

(1.13) Place hypotheses

a. Target is Velar



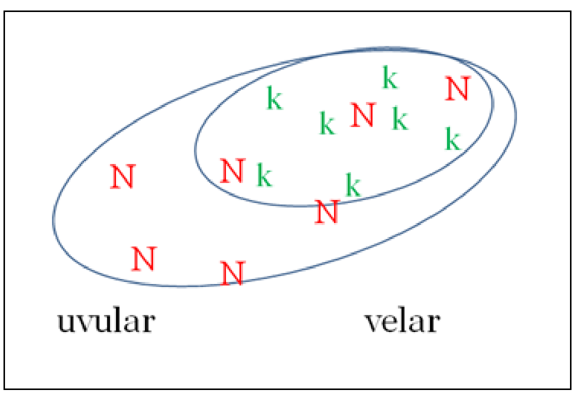
b. Target is Uvular



In (1.13a), the velar view, /N/ should completely overlap with k. In (1.13b) the uvular view, /N/ could partially overlap with /k/ (velar), but the overall distribution of /N/ must be posterior to the distribution of k.

On the other hand, the non-placeless glottal view expects /N/ to cover the whole block of k, and the whole block of /N/ must be larger than the whole block of k.

(1.14) Non-placeless glottal hypothesis



The application of this model should be limited to a controlled N; that is, an intervocalic /N/ whose flanking vowels are identical (e..g, /aNa/, /iNi/). In other words, the prediction may be different if /N/ is in other environments such as prepausal position (e.g., /aN/ 'idea'), preconsonantal position (e.g., /aNka/ 'cheapness'), or intervocalic position surrounded by different vowels (e.g., /aNi/ 'easiness'). This is because a pause, a consonant, or any other vowel could target a different position and a different type of distribution in the oral tract, which could further influence the realization of /N/. Especially for the placeless view, it is important that /N/ is on the trajectory line between identical vowels. If the context is different, the trajectory would also become different, so it follows that the position of /N/ would become different.

The /N/ as uvular hypothesis (1.13b) predicts that the distribution of the final /N/ is different from the distribution of the controlled velar tokens (i.e., /k/). On the other hand, the /N/ as velar hypothesis, as in (1.13a), predicts that the distribution of the final /N/ would completely overlap with the distribution of the controlled velar tokens. Finally, the /N/ as non-placeless glottal hypothesis (1.14) predicts that the distribution of /N/ would be scattered in the velar and uvular regions.

The mismatch between phonological place and phonetic place for /N/ is not new in de Lacy's work. I have shown that Trigo (1988) admits that placeless /N/ is realized with a velar constriction at phonetic interpretation (see sec. 1.1.1.). The difference between Trigo and de Lacy is whether the distribution of /N/ is the same as that of the velar or larger.

In either case, without phonetic evidence, the mismatch between phonology and phonetics may be mere speculation. I believe phonetic data will contribute to strengthening the empirical foundation of phonology. Cohn (2010) emphasizes that the important role of laboratory phonology is not just the presentation of data, but the theoretical contribution.

> Yet, precisely because Laboratory Phonology is not a theory as such, the collective influence of our results outside of Laboratory Phonology – on theoretical phonology and cognitive science – has not been as great as it should be, because these results are seen as *empirical* and not *theoretical*. To succeed, we need to reach out to theoretical phonology and to the broader cognitive science community to educate them about how our approach informs not only empirical matters but theoretical ones as well. (Cohn 2010: 25 [italic original])

1.1.4. Mapping Relations

This section explains the mapping relation of featural specifications between phonology and phonetics. Under the assumption that there is a direct mapping between phonology and phonetics – specified features should have discrete physical signals while unspecified features should not (Pierrehumbert 1980, Keating 1988, Cohn 1990) – place realization in these two components is quite straightforward.

In an earlier model of generative phonology (SPE), there are two components, and phonetic representations are derived from phonemic representations through phonological rules. This is shown below.

systematic phonemic representation (UR) /…/ ↓ phonological rules ↓ systematic phonetic representation […]	phonological component
↓ universal phonetic implementation rules ↓ physical output	phonetic component

Figure 1.4. SPE's derivation

Since every phonological feature is mapped onto a physical target, if a segment has a place feature in the phonology, there should be also a categorical place - having a discrete or plateau type signal - in the phonetics. Likewise, if a segment has no place feature in the phonology, then a cline or gradient type of signal can be seen in the phonetics (Keating 1988).

Various rules may apply within the phonology, modifying the mapping between input and output phonological representations. Abstracting away from such phonology-internal issues, we can consider the mapping between the phonetics and the output of the phonology.

(1.15) Match between phonetics and phonology

phonology	/F/	/0/
phonetics	[F]	[0]

F indicates that a feature is specified, and zero indicates that the feature is unspecified. In this table, we equate phonological place with the underlying or "phonemic" representation and phonetic place is reflected in the phonetic representation. Thus if we want to determine what the phonological place is, it is possible to predict it from the phonetics, and if we want to determine the phonetic place, it is possible to predict it from the phonology. In other words, bidirectional prediction is possible; from phonology to phonetics, or vice versa.

Two questions can be asked regarding this relation:

- Can the phonetics delete (phonological) features?
- Can the phonetics insert (phonological) features?

The level of the output of phonetics is equivalent to gestural representations in the sense of Articulatory Phonology (Browman & Goldstein 1986 et seq., Goldstein & Fowler 2003). The impossibility of the mismatches between phonetics and phonology follows from the basic tenets of Articulatory Phonology: *no addition or deletion* is introduced at the phonetic level. Thus the answers to the questions above are given below:

- Apparent deletion is a reduction of a gesture.
- Apparent addition is an augmentation of a gesture.

If either phonetic deletion or addition happens, then the phonological place and the phonetic place do not match as below.

(1.16) Mismatch between phonetics and phonology

phonology	/F/	/0/
phonetics	[0]	[F]

Here "phonetics" means the output of the phonology (= the "systematic phonetic representation" in Figure 1.4). In this picture, we cannot predict the phonetic place from the phonological place, and the phonological place from the phonetic place. This means that the bidirectional prediction is possible only if phonetic insertion and deletion are not allowed.

For this reason, I adopt the basic conception of Articulatory Phonology, and I define "phonological place" as place at the output of the phonology rather than place at the underlying level or the intermediate stage of the phonology, and "phonetic place" as the one in the output of phonetics. It is important to clarify these definitions, because "phonology" could encompass both the underlying phonology and the surface phonology, and likewise "phonetics" could encompass both the surface phonology and the surface phonetics. Furthermore, the concepts of phonetics and phonology may be different depending on either the theoretical frameworks or the researchers using the concepts. For example in OT, phonology consists of two levels of input and output, and some work (Benua 1997, Pater 2000, etc.) treats the output as what may be equivalent to the *input* of phonetics, but other work (Hayes 1996, Flemming 2001, Kirchner 1998, etc.) treats it as equivalent to the *output* of what is traditionally called phonetics.

The table below adds the output of phonetics below the output of phonology. This new level accomodates the physical signals of phonetics represented as ##. In order to clarify that what is discussed at this level is not symbolic elements like binary features, but physical targets, I present them as T. As shown below, the logical combinations of F/T and 0 in each column would be eight ways.

(1.17) Phonological place as place at output of phonology

Input of phonology	/F/	/F/	/F/	/F/	/0/	/0/	/0/	/0/
Output of phonology = Input of phonetics	[F]	[0]	[F]	[0]	[F]	[0]	[F]	[0]
Output of phonetics	#T#	#T#	#0#	#0#	#0#	#0#	#T#	#T#

(Shaded column: impossible)

Under the assumption of no deletion/addition at phonetics, shadowed columns are impossible correspondences. In other words, the mismatch between the output of phonology and the output of phonetics (*[0]-#F#, *[F]-#0#) is not permitted. It follows that only four ways of correspondence are allowed, as shown below.

(1.18) Correspondence between output of phonology and output of phonetics

Input of phonology	/F/	/F/	/0/	/0/	
Output of phonology = Input of phonetics	[F]	[0]	[0]	[F]	Levels under consideration in this dissertation
Output of phonetics	#T#	#0#	#0#	#T#	

In this picture, the featural specifications in the output of phonology should be detectable from the output of phonetics, and vice versa. Since the experimental results are products at the output of phonetics, they can predict the place features at the ‘output’ of phonology. In other words, this framework has a clear limitation: experimental results have nothing to say about the ‘input’ of phonology. If we see a physical target in the phonetics, the phonological specification of the feature is predicted. If there is a phonological specification, a physical target should be expected. In other words, the system enables us to make predictions bidirectionally. This is compatible with the point of view of Keating (1988) and Cohn (1990), who show that the signal shapes (e.g., plateau vs. cline) in phonetics correspond to the featural specifications (e.g., specified vs. unspecified) in phonology.

1.1.5. Summary of 1.1.

It has been shown that there is a great deal of controversy about the treatment of the phonetics-phonology interface, with regard to place features. Here are my assumptions about phonological place and phonetic place.

(1.19) Assumptions about features and targets:

a. Specified features in the output representation should be mapped onto physical targets.
b. A physical target is the reflection of some specified feature (if target, then feature).[7]
c. Place of articulation is one of the physical targets.
d. Therefore, a physical place of articulation target will be present if and only if a corresponding place specification exists in the output of phonology.

[7] I avoid saying “always” because it may be too strong. Even if there seems to be a physical target, it may not have a phonological feature. For example, the inter-speech posture of the articulators seems to have a target (e.g., Gick, Wilson, Koch & Cook 2004), but no phonological feature has been assumed. See also Wilson (2006: 96ff).

Under the assumption that phonological place is the one in the output of phonology, the implication in (1.19c) is between phonology and phonetics. The mapping from specified features to physical targets is possible, and the flow in this direction may express the process of production. Likewise, the mapping from physical targets to specified features is also possible, and the flow in this direction may express the process of perception.

The issue of the mapping poses interesting questions about the processes of production and perception: How are sounds, in spite of the phonetic variability, perceived through speakers' auditory systems, and integrated into a category of one phoneme? And how are those categories organized and produced through speakers' vocal systems? It is known that similar processes are observed crosslinguistically in the course of language acquisition (Jakobson 1941/1968). In particular, some phonemes tend to be acquired in the early stages, and others tend to be acquired in the later stages. Jakobson captures this asymmetrical relation with the notion of markedness. If the language or the dialect is same, the least marked sound should be the same sound, say /h/. The phonology of one language should derive the same type of /h/ (e.g., unspecified /h/) at the output of phonology. Then when this /h/ is realized at the level of motor control, the characteristics of targetlessness should be expected. In principle, any placeless sound should reflect this characteristic, which is testable through phonetic experiments. I will take up Japanese, because it has two kinds of allegedly placeless sounds - /h/ and N. In the following sections, arguments for and against the placelessness of these sounds will be reviewed.

1.2. Moraic Nasal

This section takes up the moraic nasal, which is one of the allegedly placeless consonants of Japanese. The placeless view of /N/ is in fact controversial, and researchers vary on whether they think /N/ is placeless or place-specified. Before I show these positions, I will briefly explain why Japanese /N/ has been called 'moraic', and discuss the situation in which an intervocalic nasal can be moraic as well.

There is no question that in Japanese, the mora plays important roles in phonology (e.g., Haraguchi 1996, Otake, Yoneyama, Cutler, & Van der Lugt 1996, Kubozono & Ota 1998, Vatikiotis-Bateson & Kelso 1993). The mora is one of the prosodic units, and can function as (i) a weight bearing unit to distinguish syllables, (ii) a timing unit for speech rhythm, (iii) a metrical unit in poetry, or (iv) a tone-bearing unit to predict the accent location. The examples below show moraic /N/ vs. non-moraic nasals.

(1.20) Moraic vs. non-moraic contrast

a. moraic /N/		b. non-moraic nasals	
/a**N**.ma/	'masseur'	/a.**m**a/	'nun'
/ho**N**.ne/	'real intention'	/ho.**n**e/	'bones'
/saN.ma/	'saury'[8]	/sa.**m**a/	'looks'
/hó**N**.no:/	'instinct'	/ho.**n**o:/	'flare'

Moraic /N/ in Tokyo Japanese always appears in postvocalic position. Thus, if we follow a well-accepted syllabification procedure, postvocalic /N/ should be syllabified as a coda. On the other hand, a non-moraic nasal always appears in prevocalic position, and thus it is syllabified as an onset.

Moras can coexist with syllables as phonological units in Japanese. There is some evidence that not only the mora but also the syllable is necessary to predict the location of accent in loanwords.

(1.21) Moras and syllables for accent location in loanwords

a.	pá.ʤa.ma	'pajáma'	antepenult μ	antepenult σ
b.	pai.rót.to	'pílot'	antepenult μ	penult σ
c.	hoo.mú.raN	'hóme rùn'	antepenult μ	penult σ
d.	ka.réN.daa	'cálendar'	pre-antepenult μ	penult σ
e.	e.su.ka.rée.taa	'éscalator'	pre-antepenult μ	penult σ

If we use only the mora, the accent location of loanwords would be on the antepenultimate mora (1.21a-c) or pre-antepenultimate mora (1.21d, e). If we use only the syllable, it would be on the antepenultimate syllable (1.21a) or penultimate syllable (1.21b-e).

[8] A long slender-bodied edible marine fish with an elongated snout.

Either way, no coherent generalization can be attained. These examples show that both mora and syllable are necessary for a coherent account of the accent location in loanwords: the accent falls on the ‘syllable’ containing the antepenultimate ‘mora’ (McCawley 1968). (But see Giriko 2006 for exceptional behavior of […iN]#.)

One of the interesting characteristics of the Japanese moraic nasal can be found in intervocalic position. It resists being syllabified as an onset, against the onset maximization principle. It stays in the coda and still counts as one mora. It is not clear whether having an independent oral place is a condition of becoming an onset. If /N/ is missing the oral place feature, and when /N/ is followed by a stop consonant, unarguably /N/ acquires an oral place feature from the consonant. But if /N/ is followed by a fricative, glide, or vowel, it sounds as if the oral place is missing .

The diversity of different descriptions/opinions can be categorized into three groups: i) placeless views (Grignon 1984, Itô 1986, Trigo 1988, Yip 1991, Kuroda 1979[1965]), ii) place-specified views (Block 1946, Vance 1987, Uemura 1997b), and iii) somewhere between the two (de Lacy 2002, 2006, 2009).

1.2.1. Arguments for Placeless Nasal

1.2.1.1. Predictability

An argument of underlying placelessness is the predictability of place. One of the crosslinguistically observed patterns for placeless /N/ is nasal place assimilation. There is a general agreement that when Japanese /N/ (e.g., [hoN] ‘book’) is followed by a stop consonant, nasal place is assimilated to the place of the stop, being realized as either [m, n, ɲ, ŋ] (e.g., [hommo] ‘book too’, [honda] ‘is book’, [hoɲɲi] ‘in book’, [hoŋka] ‘book?’) (Examples are from Vance (1987: 35)).

In underspecification theory, lexical representations should be minimally specified. There are different versions of underspecification theories. The oldest theory of underspecification is ‘archiphonemic’ underspecification (Jakobson 1929, Trubetzkoy 1929, 1936, Martinet 1936; see Akamatsu 1988). The essence of the theory was taken over in the field of generative phonology, and different versions of underspecification theory have been developed. In ‘radical’ underspecification theory (Pulleyblank 1982, 1983, 1988a, b, Kiparsky 1984, Archangeli 1984, 1988, Itô & Mester 1986, Archangeli & Pulleyblank 1989, Mohanan 1991, Stemberger 1991, among others), only marked values are specified in the lexicon and language-specific default rules fill in the unmarked value. [9]

In 'contrastive' underspecification theory (Steriade 1987b, Clements 1988, Mester & Itô 1989), only contrastive values are specified, or equivalently, only redundant values are underspecified in the lexicon. Moreover, 'minimally contrastive' underspecification theory (Avery & Rice 1989a, b) takes into account the markedness of place features, and claims that the place features are specified in the underlying representation only if the feature node dominates a secondary feature. Despite all these differences, there is a general consensus that place features are privative (mono-valued or unary), based on the evidence that place features can combine with each other to form multiply-articulated segments and that the negative values are not referred to by phonological rules (Lombardi 1995, Steriade 1995).

Each version of underspecification theory makes a different prediction about what features are underspecified in the overall lexicon. However, phonologists have noticed that some features or feature values are recurrently undergoers of rules, unlike the other features or feature values. Much effort has been made in explaining such phonological asymmetries.

Place assimilation is one of the crosslinguistically most common phenomena, and one of the most frequent undergoers are nasals. This is because, compared to oral consonants, nasal consonants have acoustically weak cues for place, especially when they are in coda position (Krakow 1993). The most frequent trigger for nasal place assimilation is a stop consonant (Padgett 1994, 1995). Many researchers take or at least have taken this predictability of the place of /N/ followed by a stop consonant to argue for the underspecified status for Place for /N/ (e.g., Kiparsky 1984, Padgett 1994, 1995, Pater 1999, Kager 1999: 59). Japanese /N/ is not an exception (cf. Itô & Mester 1993).

In a constraint-based analysis of OT, the predictability of place features of /N/ in nasal place assimilation could be expressed as the dominance of a constraint ICC(PLACE) which requires the identity of place in a cluster (Pulleyblank 1997).

[9] Archangeli (1989) argued that the specified values could vary from language to language.

(1.22) Nasal place assimilation in OT

	/N p/	ICC(PLACE)	HAVEPLACE	NO-SPREAD (PLACE)
a.	N][p | Lab		*!	
b.	ɴ][p | | Phar Lab	*!		
c.	n][p | | Cor Lab	*!		
d. ☞	m][p ╲| Lab			*

N indicates an 'archinasal' (Trubetzkoy 1931[1971]) or a nasal without place specification in phonology. [N] is different from small capital [ɴ] which is the uvular nasal. Note that this orthographic distinction is needed because both types of nasals play an important role in my account of Japanese. As shown above, the placeless nasal [N] (written in big capitals) in (a) and the uvular nasal [ɴ] (written in small capitals) in (b) could be candidates for a sequence of nasal and obstruent. But placeless nasal [N] violates HAVEPLACE, 'Every segment must have some Place' (Padgett 1995, Parker 2001), while the uvular nasal does not because it has Pharyngeal place (Trigo 1991). In order to avoid the confusion between the two of them, I will use /N/ (written in big capitals) for a placeless nasal throughout this thesis, though my use of / / is not intended to imply that all instances of N are underlying. Notice that whatever the input is, say, /Np/, /np/, or /mp/, the same result is attained. This is called Richness of the Base (ROB) – no restriction is imposed on inputs, and the evaluation takes place only in the output of phonology. Thus, [N] in candidate (a) is eliminated due to the violation of HAVEPLACE. Candidate (d) having nasal place assimilation will be a winner, because it obeys the most dominant constraint ICC(PLACE) as well as HAVEPLACE.

1.2.1.2. Debuccalization

Debuccalization - loss of oral place from consonants - is one of the arguments for phonological placelessness. Thus this is a case of placelessness in the output rather than input. McCarthy (2007: 92) states "In the case of obstruents, debuccalization typically leaves [h] or [ʔ] behind. When nasals debuccalize, the result is usually [N]".

It is well known that debuccalization of both obstruents and nasals is attested in Kagoshima Japanese (Haraguchi 1984, Kaneko & Kawahara 2002). In Tokyo Japanese, nasal debuccalization is dominant. Whether [N] has an oral place feature or not is a sensitive issue (see sec. 2.3 for discussion), but in this section, I will review the cases where either /m/, /n/, or /ŋ/ are assumed to be debuccalized to [N].

Trigo (1988) states that the place specification of the syllable-final nasal of loanwords seems to be lost in Japanese.[10]

(1.23) English loans

	English	Modern Japanese	
a.	hæm	hamɯ	'ham'
b.	wɑʃintən	waʃintoN	'Washington'
c.	sɔŋ	soŋgɯ	'song'
d.	pudiŋ	pɯɾiN	'pudding'

Trigo's examples (1.23a-c) show that only the coronal nasal is debuccalized, while the labial nasal is realized as [mɯ], and the velar nasal is realized as [ŋgɯ]. These patterns are probably predominant, but there are examples where velar nasals are debuccalized to [N] (as in d), for example, [pudiŋ] > [pɯɾiN] 'pudding', [piŋpɑŋ] > [pimpoN] 'ping-pong', [tʌŋ] > [taN] 'tongue', [kʊŋ] > [kɯN] 'Kung', [hoŋ koŋ] > [hoN koN] 'Hong Kong' and [pikiŋ] > [pekiN] 'Peking'. It is unclear how the choice is made for [N] (cf. Heffernan 2005). These cases show

[10] However, [n] in loanwords of French origin is consistently followed by an epenthetic /u/ (e.g. *Cannes* [kan] > [kannu]). Peperkamp, Vendelin & Nakamura (2008) ascribe this to the strong vocalic release of French final [n] that Japanese listeners perceive. On the other hand, French nasalized vowels are transformed into a vowel plus /N/ sequence (e.g., *dessin* 'rough sketch' [dɛsɛ̃] > [dessaN] *jupon* 'trousers' [ʒypɔ̃] > [zuboN] *roman* 'spirit of adventure' [ʁomɑ̃] > [romaN]). So the contrast of [n] and VN in French is maintained.

that the contrast between [n] vs. [ŋ] in English loans is not completely maintained, but can be taken as being partially neutralized to [N] in the output of phonology. Debuccalization of [m] from English loans has not been found.

Debuccalization is also seen in the Sino-Japanese vocabulary. It is said that N-final Sino-Japanese words reflect historical debuccalization when Middle Japanese adopted Middle Chinese loanwords (see Heffernan 2007, Frellesvig 1989).

(1.24) Debuccalization in Sino-Japanese (cf. Heffernan 2007: 62)

	Middle Chinese	Middle Japanese	Modern Japanese	Orthography	
a.	kim	kimu	kiN	金	‘gold’
b.	ṣan	saN	saN	山	‘mountain’
c.	pəŋ	poũ	hou	崩	‘collapse’
d.	kiajŋ	keĩ	kyou, kei	京	‘capital’

As seen above, in Middle Japanese, only [n] is debuccalized to [N]. Interestingly, the original contrast of Middle Chinese /m, n, ŋ/ was maintained in terms of either epenthesis, debuccalization, or vocalization respectively. However, in Modern Japanese, the contrast between [m] (after the deletion of [u]) vs. [N] is neutralized to [N].

In both English and Chinese loans, all the place specifications [m, n, ŋ] in the coda in the source language have been eventually lost in Modern Japanese. This fact suggests that the Coda Condition (Itô 1986, 1989, Itô & Mester 1993) has been highly ranked at least since Middle Japanese. Coda Condition says that no independent place is licensed in coda position.

(1.25) Coda Condition (Itô 1986, 1989, Itô & Mester 1993)

$$\begin{array}{l} *\ \ C\,]_{\sigma} \\ \quad\ \ | \\ [\text{PLACE}] \end{array}$$

Thus, in general, a singly-linked coda consonant is prohibited (cf. Kawasaki 1998). Compared to [m, n] in the coda, [ŋ] in the coda shows a variety of realizations such as epenthesis and debuccalization (English loans) or becomes a nasalized vowel (Chinese origin).

What is interesting is that [n] in the coda is more likely than [m] in the coda to be debuccalized to N. In other words, the labial nasal resists losing its place specification more strongly than the coronal nasal. This observation supports the ranking of FAITH[LAB] » FAITH[COR], due to the relative perceptibility of the two (Howe & Pulleyblank 2004). The asymmetry is summarized in (1.26). Among the candidates, C]$_\sigma$ indicates a coda consonant, and [C indicates an onset consonant.

(1.26) Debuccalization of Middle Japanese and Modern Japanese in OT

(i) Middle Japanese: Debuccalization of [N] only (/m/ resists changing)

		CODACOND	**FAITH[LAB]**	DEP-V	HAVEPLACE	FAITH[COR]
/N/	a. ☞ N]$_\sigma$				*	*
	b. n]$_\sigma$	*!				
	c. [nV			*!		
	d. m]$_\sigma$	*!				*
/m/	a. N]$_\sigma$		*!		*	
	b. n]$_\sigma$	*!	*			
	c. m]$_\sigma$	*!				
	d. ☞ [mV			*		

(ii) Modern Japanese: Debuccalization of /N/ and /m/

		CODACOND	DEP-V	**FAITH[LAB]**	HAVEPLACE	FAITH[COR]
N	a. ☞ N]$_\sigma$				*	*
	b. n]$_\sigma$	*!				
	c. [nV		*!			
	d. m]$_\sigma$	*!				*
/m/	a. ☞ N]$_\sigma$			*	*	
	b. n]$_\sigma$	*!		*		
	c. m]$_\sigma$	*!				
	d. [mV		*!			

The ranking between HAVEPLACE and FAITH[COR] does not matter here, as indicated by the dotted line. In Middle Japanese, due to the high ranking of FAITH[LAB], /m/ does not get debuccalized while /N/ does. But in Modern Japanese FAITH[LAB] is ranked below Dep-V, therefore /m/ as well as /N/ gets debuccalized.

The forms on the lefthand side below are not well-formed, due to the violation of the Coda Condition.

(1.27) Source words are repaired due to Coda Condition

a.	*[kæt̲]	→	[kʲat.to]	'cat'
b.	*[soŋ̲]	→	[soŋ.gu]	'song'
c.	*[hæm̲]	→	[ha.mu]	'ham'
d.	*[pu.dɪŋ]	→	[pu.ɾiN]	'pudding'

In the surface form, repairs are executed to conform to the Coda Condition (see Katayama (1998) for a constraint-based analysis of loanwords in Japanese). For example, a coda consonant in the source words either becomes the first segment of a geminate (a), homorganic to the onset of the next syllable (b), the onset (c), or debuccalized (d). The singly-linked coda in final [N] in (d) does not violate the Coda Condition because [N] is unspecified for place.

Debuccalization is not limited to foreign loanwords, but is found in native vocabulary items as well. A famous example is that the negative particle *N* is historically derived from /nu/ (or /mu/) in Middle Japanese.

(1.28) Debuccalization of /nu/

a.	deki-nu	→	deki-*N*	'be able to NEG'
b.	sira-nu	→	sira-*N*	'know NEG'

The forms ending with –nu are obsolete but the debuccalized forms are still often heard in the speech of old men in some dialects. /N/ was first used in colloquial forms, and came to be more widespread in the western part of Japan (Kojien dictionary). [11]

A form *saN* is a casual form of the honorific suffix *sama* which usually follows a person's name, or some phrases to show politeness.

[11] In Yoshida (1995: 118-121), N is [ɰ̃] and /nu/ [nɯ]. She suggests that the similar phonetic property of these two is supported by the debuccalization and the rarity of /nu/-ending words.

(1.29) Debuccalization of /ma/

a.	Suzuki sama	→	Suzuki saN	'Mr./Mrs./Ms. Suzuki'
b.	oku sama	→	oku saN	'wife'
c.	o-machidoo sama	→	o machidoo saN	Thank you for waiting'
d.	o-nii chama	→	o nii chaN	'(my) brother' (child talk)

In these cases, the process may be captured through apocope; thus /ma/ > /m/ > N. Another potential case of debuccalization is nasal syllabification of *no* as a nominalizer or possessive marker.

(1.30) Nasal syllabification of NOM. /Poss. /no/ (Examples from Hasegawa 1979: 128)

a.	kuru no nara	→	kuru N nara	If it is that …come'
	come NOM. Copula-cond.			
b.	Taro no da	→	taro N da	'It is Taro's.'
	Taro POSS. Copula-pres.			

The nasal syllabification occurs to *no* either as a nominalizer (as in (1.30a)) or a possessive marker (as in (1.30b)) before a copula /nar-, -da/ (Nishikawa 1987: 149-152).[12] Debuccalization may occur to the particle *ni* 'dative or directional' as well (e.g., gakusha ni naru scholar DAT. become > gakusha N naru 'become a scholar') (Hasegawa 1979: 128), but Nishikawa (1987) states *ni* to N syllabification is more restrictive than *no* to N syllabification. Intuitively, the nasal syllabification is a casual speech rule, but Hasegawa notes the syllabicized form /N/ can occur in a fairly formal or polite expression. The entire picture of the nasal syllabification is outside the scope of this dissertation, but all these cases generally support that debuccalization of /m, n/ > [N] is productive in modern standard Japanese.

[12] The nasal syllabification also occurs in the following phrases: sono toki (that time) > soN toki 'that time', soko no tokoro (that POSS. spot) > soko N tokoro 'that spot', kodomo no toki (child POSS. time) > kodomo N toki 'in childhood', watashi no uchi (I POSS. house) > watashi N chi 'my house'.

1.2.1.3. High Articulatory Variability

The most important evidence for phonetic placelessness is high articulatory variability. The phonetic realization of /N/ in prepausal position is, borrowing from Yip (1991: 69), "unreleased, either velar or uvular, and the oral closure may not be complete" (see also McCawley 1968: 84).

As support for the high articulatory variability of N, Trigo's observation should be added here. /N/ is not unique to Japanese, but crosslinguistically attested. She calls it a "placeless nasal glide". Trigo (1988: 25) states,

> Glide-like transitional elements similar to Sanskrit anusvara transcribed here as [N] have been described in several languages […] <u>The phonetic description of these nasals varies because their point of articulation and stricture is indeterminate</u>. In fact, the phonetic description of [N] suggests that it lacks a point of articulation and that it is not a stop, but a glide in the same group with [h] and [ʔ].[emphasis N.Y.]

Trigo's statement that the phonetic description of /N/ varies seems to hold true to Japanese /N/ as well. There are diverse opinions about the articulatory location of prepausal N: Based on auditory impressions, McCawley (1968: 84) describes it as a nasalized continuation of the preceding vowel or a velar nasal. Bloch (1946, 1950) states it is coronal or velar. Both seem to suggest a wide range of variations for N.

Kuroda's (1979) statement seems to support this point:

> The phonetic realization of the nasalized consonantal mora may best be described as <u>a nasalized continuous transition</u> from the preceding segment to the following one. […] If the following segment is not a (true) consonant, the nasalized consonant can be phonetically described as <u>a nasalized vowel of varying degree of closure and point of articulation</u>. […] we will represent the phonetic realization of the nasalized mora consonant before a vowel or a word boundary by ṽ. (Kuroda 1979: 201-202, cf. Arisaka 1940; emphasis N. Y.)

Examples of Kuroda's transcription are given below.

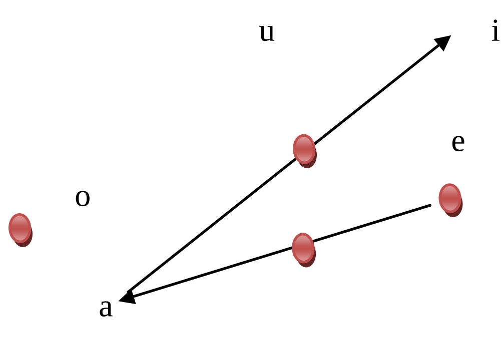
(1.31) Kuroda’s (1979) transcription

a.	/taN.i/	[taṽi]	‘unit’
b.	/seN.eN/	[seṽeN]	‘one thousand yen’
c.	/reN.ai/	[reṽai]	‘love’
d.	/hoN.o/	[hoṽo]	‘book-GEN’

Such a “continuous transition” could happen if /N/ lacks a constriction in the oral cavity. The point that /N/ loses the constriction in the oral cavity is also reflected in his suggestion of the symbol ṽ. This symbol in the output indicates that the segment has no specific vowel quality and is variable according to the neighboring sounds.

Along with the quality of continuous transition, the high variability of both closure degree and point of articulation suggests that /N/ is unspecified for both constriction degree and constriction location. The symbol ṽ suggests it has no distinct categorical constriction degree or place in the oral cavity and is variable depending on the contexts. The following sketch illustrates the point. The lefthand side is back and the righthand side is front in the oral cavity. The four red dots below indicate the expected position for /N/ in each example that I introduced in (1.31). Arrows show the hypothetical “continuous transition” of the peak of tongue from the first vowel to the second vowel (i.e., [a] to [i], and [e] to [a]) through /N/. The relative position of the five vowels of Japanese follows Uemura (1997a), which is based on x-ray data.

(1.32) Various predicted positions of /N/ in aṽi, eṽe, eṽa, oṽo



The position of ṽ in [taṽi] should be somewhere between [a] and [i], ṽ in [seṽeN] should be close to [e], ṽ in [reṽai] should be between [e] and [a], and ṽ in [hoṽo] should be close to [o]. As a result, the position of ṽ can be variable in a wide range in the oral cavity: It is not just close to any of the vowels [i, e, a, o, u], but also can be positioned in the trajectory between any combination of two Japanese vowels.

Uemura & Takada (1990: 514-519), based on x-ray observations, also suggest that intervocalic /N/ has a wide range of variability. They explicitly state that i) one of the important characteristics of the intervocalic nasalized vowel derived from /N/ is in the transitional quality from the vowel immediately before /N/ to the vowel, semivowel or fricative immediately after /N/, and ii) the part of the tongue that is raised, the degree of the raising, the process of the raising, and the degree of the velum lowering are all subject to the types of the adjacent phonemes, and the combinations of the phonemes before and after /N/.

1.2.2. Arguments Against Placeless Nasal

1.2.2.1. Uvular in Prepausal Position

Some researchers do not admit too much variability for /N/ in word-final position: The major view of the place of /N/ according to this position is that it is either uvular (Hattori 1930), or velar (Sakuma 1929[1963]). Later x-ray photographs suggest that the place of /N/ may be generally uvular (Nakano 1969: 220, Naito 1961: 118, Vance 1987). But Uemura & Takada (1990) and Uemura (1997a) suggest that the position shifts depending on the preceding vowel.

Uemura's (1997a) generalization about prepausal /N/ is that the place of /N/ is predictable from the backness of the preceding vowel; he describes /N/ as velar after front vowels and uvular after back vowels, as below.

(1.33) Word-final nasal (Data from Uemura 1997a: 218)

a. /bíɴ/ [biŋ̲] 'bottle'
b. /téɴ/ [teŋ̲] 'sky'
c. /páɴ/ [paɴ̲] 'bread'
d. /hóɴ/ [hoɴ̲] 'book'
e. /búɴ/ [bɯɴ̲] 'sentence'

As shown in the phonemic representations in the leftmost column, Uemura assumes the phoneme of the segment in question is a uvular nasal. Obviously the concept of archinasal is not adopted here. Rather the velar nasal is assumed to appear allophonically.[13] The basis for this interpretation - whether impressionistic, acoustic or articulatory - is not stated in the original source, but it should be reasonable to say that it is not just impressionistic but also based on articulatory data, because Uemura conducted an X-ray investigation of his own articulation of this sound in Uemura & Takada (1990).

Uemura & Takada (1990: 511) suggest that the place of articulation of /N/ is also slightly different even after vowels having the same backness: /i/ shifts /N/ further forward than /e/, /o/ shifts /N/ further backward than /a/, and /a/ shifts /N/ further backward than /u/. Thus the frontness of /N/ can be ordered as iN > eN > uN > aN > oN. Uemura & Takada (1990) compared the position of /N/ in /i$\underline{\text{N}}$, e$\underline{\text{N}}$/ and /k/ in /$\underline{\text{k}}$o(:), $\underline{\text{g}}$o(:)/ for a single subject, and found that the series of /N/ as a whole is slightly further back than the series of /k/ (ibid: 514), suggesting that the targeted area of /N/ is distinguished from /k/, and is located further back than /k/. Although the relative location of /N/ and /k/ is clear, this fact gives no conclusive evidence as to where the boundary of velar and uvular is, thus leaving many possibilities still open as below.

(1.34) Boundary between velar and uvular

Velar ← → Uvular

ik > ek > uk > ak > ok > iN > eN > uN > aN > oN

↑ ↑ ↑ ↑ ↑ ↑ ⇧ ↑ ↑

Uemura & Takada (1990) note that PoA of /í$\underline{\text{N}}$/ and /é$\underline{\text{N}}$/ can be interpreted as velar or uvular, and avoid a conclusive statement. Uemura (1997a) decides to interpret it as velar phonetically, which suggests the boundary is set after /éɴ/ as shown with the big arrow above. But as the small arrows show, the boundary could be near [ik], or could be near [oN], or somewhere between

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[13] The shift from uvular to velar could be obtained from a spreading rule such as the one assumed in Clements & Hume's (1995) geometry model, where C-place and V-place are embodied under the root node. A possible analysis is to spread the coronal feature under the V-place node of the front vowel to the V-place node of /ɴ/, and change it to [ɴ^j]. Since there is no such segment, a special interpretation rule may be needed to derive [ŋ] from [ɴ^j].

them. Because only one subject participated in Uemura and Takada's (1990) study, another remaining problem is whether the pattern observed here applies to all speakers of Tokyo Japanese.

1.2.2.2. Assimilation at Intervocalic Position

Within the place-specified view, where /N/ receives its place specification contextually, there is no agreement about whether the place of /N/ is received from the vowel on the left or the vowel on the right.

1.2.2.2.1. Regressive Assimilation

After Uemura & Takada (1990), Uemura (1997a) proposes a slightly different view:

> [w]hen /N/ is immediately preceded by a vowel phoneme, and is immediately followed by a vowel or a glide, or followed by a vowel phoneme across /h~hj/, […] /N/ would become a glide-like nasalized vowel, articulated at a place <u>closer to the following sound's, than to an intermediate place between the preceding vowel and the following vowel or semivowel</u> [translation, emphasis N.Y.]. (Uemura 1997a: 219)

It seems clear from this statement that Uemura is not a supporter of the placeless view of /N/: /N/ is neither of "transitional quality", nor midway between the adjacent vowels, but its height and backness gets close to that of the following vowel. Thus the possibility here is that /N/ could acquire a place feature from the following segment.

Below is the list of Uemura (1997a)'s transcriptions of intervocalic /N/. (The original text uses [˺] to indicate that the preceding vowel is accented, but in IPA it means "no audible release", so in order to avoid confusion of different definitions, I will use the accent mark [´] to denote the accented vowel.)

(1.35) Intervocalic moraic nasal: 3 kinds of nasalized vowel (Uemura 1997a: 218)

a. [ɯ̃̈] [14]

Before /hw/	/dóɴhwaɴ/	[doɯ̃̈ɸaɴ]	ドンファン	'Don Juan'
Before /w/	/deɴwa/	[deɯ̃̈wa]	電話	'telephone'
Before /w/	/huɴwári/	[ɸɯɯ̃̈waɾi]	ふんわり	'fluffy'
Before /u/	/aɴuɴ/	[aɯ̃̈ɯɴ]	暗雲	'dark clouds'

b. [ĩ]

Before /hj/	/séɴhjaku/	[seĩçakɯ]	千百	'one thousand and one hundred'
Before /j/	/hóɴja/	[hoĩja]	本屋	'book store'
Before /j/	/siɴju:/	[ʃiĩjɯ:]	親友	'close friend'
Before /i/	/táɴi/	[taĩi]	単位	'unit'

c. [ə̃]

Before /h/	/zeɴhaɴ/	[dzeə̃haɴ]	前半	'the former half'
Before /e/	/seɴeɴ/	[seə̃eŋ]	千円	'one thousand yen'
Before /a/	/reɴai/	[reə̃ai]	恋愛	'love'
Before /o/	/hóɴo/	[hoə̃o]	本を	'book-GEN'

The patterns above can be derived with the following three rules:

(1.36) Three nasalized vowels as intervocalic /N/ based on Uemura (1997a)

a. /ɴ/ → [ɯ̃̈] / ___ /(h)w, u/

b. /ɴ/ → [ĩ] / ___ /(h)j, i/

c. /ɴ/ → [ə̃] /___ /(h)a, e, o/

[14] Double dots above indicate that the sound is centralized.

The notation '(h)' indicates a context that can be optionally considered for the rule.[15] If this generalization is correct, place feature spreading should be regressive and /N/ can be specified for place in the output of the phonology.

Yatabe (1987: 17) states that [ɴ] appears before a pause and before a continuant. But for the intervocalic /N/, he suggests that it alternates with a nasalized vowel, whose place is completely identical to that of the following vowel.

(1.37) Intervocalic moraic nasal (Yatabe 1987: 17)

a.	before [j]	/kiNjuː/	[kiĩjɯː]	金融	'finance'
b.	before [i]	/kaNi/	[kaĩi]	簡易	'easiness'
c.	before [w]	/hoNwa/	[hoũwa]	本は	'book-NOM'
d.	before [ɯ]	/teNuN/	[teɯ̃ɯɴ]	天運	'destiny'
e.	before [e]	/kiNeN/	[kiẽeɴ]	禁煙	'non-smoking'
f.	before [o]	/zeNoN/	[zeõoɴ]	全音	'a whole tone'
g.	before [a]	/zeNaku/	[zeãakɯ]	善悪	'good and evil'

Yatabe takes a strong position that the preceding vowel has no influence on the quality of /N/.

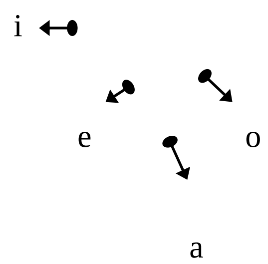
Hattori (1951: 123) states that the quality of the nasalized vowel agrees with the following vowel (e.g., /taNi/ > [taĩ̠i] 'unit'), but he expresses the view that the place is not completely identical to the following vowel:

> retracted from [i] when [Ṽ] is followed by [i]; retracted and raised from [e] when [Ṽ] is followed by [e]; fronted and raised from [o] when [Ṽ] is followed by [o]: and raised and fronted from [a] when [Ṽ] is followed by [a] (translated in Akamatsu (1997: 300)).

[15] The precise phonetic quality above being left aside, Akamatsu (1997: 300) would agree with the transparency of /h/, as he states, "When [ṽ] occurs before [h], [ç], [ɸ] (…), the qualities of [ṽ] are similar to those of [ṽ] when occurring before [a], [e], [o], [i] or [ɯ], as the case may be". The difference between Uemura (1997a) and Akamatsu (1997) is the contexts where the transparency is possible. Akamatsu's statement implies that /h/ before all kinds of vowels is transparent, while from Uemura's (1997a) examples, it is unclear whether it is so. And Uemura's examples include /h/ before glides /j, w/, but Akamatsu's do not.

The shift of [Ṽ] to the second vowel in Hattori's observation is illustrated below. (The lefthand side is the front of the oral cavity, and the righthand side is the back of the oral cavity. The relative position of vowels follows Uemura (1997a). Dots indicate the tongue position of [Ṽ], and the line from the dot to the arrow shows that the tongue position shifts in this way to the specified following vowel.)

(1.38) Ṽ assimilating to the following vowel



This suggests that the positions of the nasalized vowels are close to and predictable from the quality of the following vowel, though they are not completely identical to the following vowel.

Unlike Uemura (1997a), Hattori (1951) does not formulate rules, so it is not clear whether some vowels form a natural class in regard to the phonetic output. But in his earlier work (Hattori 1930: 46), he states "if we ignore small differences, those that […] precede a vowel are something like [ĩ] before /i e/ and something like [ɯ̃] before /a o u/". (translated in Vance 1987: 36). Thus, now we know that there are two different views: Uemura (1997a) assumes that the phonetic quality of intervocalic /N/ is sensitive to height and backness, while Hattori (1930) assumes that it is sensitive to backness.

1.2.2.2.2. Progressive Assimilation

Grignon (1984) also seems to support the place-specified view. But in her generalization, the spreading occurs from left to right (e.g., /taN.i/ > [taã̠i] 'unit'). This could be supported by the phonological structure of the syllable; the coda nasal has a strong affinity with the nucleus, sharing a rhyme.

A similar view is expressed in Nakaoka & Muraki (1990), who propose a progressive assimilation rule of /N/ given below.

(1.39) Nakaoka & Muraki's (1990: 145) progressive assimilation rule

$$/N/ \rightarrow [V_1, +\text{nasal}]\ /\ V_1 \_\_ [+\text{cont}]$$

Although the rule states that the place of /N/ is received from the preceding vowel, Nakaoka & Muraki (1990) admit that the rule above does not completely characterize the behavior of intervocalic /N/, because in fact, /N/ assimilates to V_2 as well, but this information is missing in the structural change. Still, they choose V1 rather than V2 as a provider of place in the rule, mainly because they take into consideration that intervocalic /N/ is often a problematic sound for learners of Japanese, and the rule description can indicate to them that /N/ should be pronounced without oral closure just like the preceding vowel.

Descriptive support for progressive spreading can be adduced from Arisaka (1940).

(1.40) Arisaka (1940: 83) (cited in Akamatsu 1997: 300)

(i) After high vowels

a. [ĩ] after /i/ [iĩe], [iĩ̘a], iĩo]

b. [ɯ̃] after /u/ [ɯɯ̝̃e], [ɯɯ̃a], [ɯɯ̃o]

(ii) After mid vowels

a. [ẽ̝] after /e/ [eẽ̝o̝], [eẽ̝e̘], [eẽ̝˕a]

b. [õ̝] after /o/ [oõ̝e], [oõ̝a], [oõ̝o]

(iii) After low vowels

a. [ɤ] after /a/ and before /o, a/ [ãɤ̝a], [aɤ̝̃o]

b. [ẽ̝˕] after /a/ and before /e/ [aẽ̝˕e]

In the descriptions in (i-ii) where /N/ is preceded by high and mid vowels, spreading from the left is straightforward. But after a low vowel, the situation is not so simple. The symbol [ɤ] Arisaka employs is meant to be unrounded [o]. His addition of the diacritic [̝] shows that in his opinion, the tongue is raised higher than in any of the surrounding vowels; in other words, an oral constriction is happening to intervocalic /N/. If there is no place, there should be no oral constriction, so this description suggests that he considers /N/ as having an independent place.

A further comment is that Akamatsu (1997: 299) thinks nasalized vowels after high vowels as in (1.40i) should have a higher tongue position than the high vowels. He suggests that /N/ also has an independent oral constriction degree, which is not just given by the adjacent segment.

1.2.2.3. Neutralized /N/ is Non-Placeless Glottal

De Lacy (2002 et seq.) states that the neutralized /N/ is a non-placeless glottal. According to this hypothesis, the PoA of /N/ is not velar or uvular, but phonologically it is glottal. Whether it is claimed to be glottal or not and whether it is claimed to be placeless or not are separate issues. In this section, setting aside his claim that /N/ is "glottal", I will review the evidence for non-placelessness – i.e., the place-specified status of /N/.

Placelessness has been ambiguously defined in the previous literature. What de Lacy argues against is the representational definition of placelessness. In the representational approach (Clements 1987, Sagey 1986, Hayes 1986, Steriade 1987a, Stemberger 1993, among others), two assumptions are made. One is that unmarked values are not present in phonological representations – so the less marked a segment is, the less complex its structure should be. The other is that lack of specification is universal; so if a glottal is placeless, this should hold true for every language. It has been controversial whether the placeless segment is coronal (Paradis & Prunet 1991) rather than glottal, but no matter what the segment is, it is predicted that a placeless segment should be the output of neutralization and the target of assimilation, but should never undergo dissimilation, trigger assimilation, or block place-related processes.

1.2.2.4. Articulatory Conflict of *Ni

A sequence of /N/ followed by an onsetless syllable (i.e., …VN.V…) is perfectly legal in Japanese phonology, but in colloquial speech at a relatively fast tempo, /N/ can disappear or become a nasalized vowel. The environment of /N/-deletion seems to be limited: Kuwamoto (2004) suggests, based on his auditory impression, it happens only when the following syllable is /iN/.

(1.41) /N/ + /i/ is unstable (Kuwamoto 2004: 15)

a. zeN.iN zee.iN 'all members'
b. geN.iN gee.iN 'reason'
c. teN.iN tee.iN 'clerk'

/N/ is deleted before /iN/, and instead the place is received by the preceding vowel and a long vowel is produced. Since the syllable weight is kept, this can be seen as compensatory lengthening. The next examples show that the same process never occurs with a sequence of /N/ followed by /u, e, o, a/.

(1.42) /N/ + /u, e, o, a/ is stable (Kuwamoto 2004: 15)

a. keN.eN *kee.eN 'hatred of smoking'
b. hoN.aN *hoo.aN 'adaptation'
c. haN.oN *haa.oN 'a half tone'
d. aN.uN *aa.uN 'dark clouds'

Kuwamoto states that syllables ending with /N/ are usually stable and resist deletion in various phonological processes, but the example of /N/-deletion before /iN/ shows that syllables ending with /N/ are unstable before onsetless syllables. The instability of /N/ in this context is also supported by a particular example of metathesis - fuN.iki > fu.iN.ki 'atmosphere' - which is becoming widespread in colloquial speech (p.c. Yuji Kuwamoto).

The remaining question is why it is only before /i/ that /N/ is unstable, although /N/ is stable before the rest of the vowels.[16] I will take this evidence as possible support for the view that /N/ may have a pharyngeal-like property (rather than being placeless). The sequence in question - /N.i/ - is subject to the universal constraint banning sequences of pharyngeals plus high front vowels, and /N/ deletion can be considered as a repair strategy.

If it is true that /N/ has a pharyngeal quality, then this sequence may have an articulatory conflict between the tongue root and the tongue dorsum. Gick & Wilson (2006) argue that conflicting targets, between tongue root backing/lowering and tongue dorsum fronting/raising,

[16] The data that he presents to show that N is unstable before /iN/ include /maNiN/ > [maain] 'full of people'. I have not heard such a phonetic realization. In contrast, /zeNiN/ > [zeeiN] is very common.

develop crosslinguistically diverse repair strategies (see sec. 1.3.2.1. for more examples). /N/-deletion and metathesis shown in this section can be also considered as repair strategies. These recurrent patterns should be phonologically grounded, in that certain featural combinations are avoided due to "antagonistic" featural combinations (Archangeli & Pulleyblank 1994), e.g., pharyngeals [−high, +low, +back] (SPE: 307) versus high vowels [+high, −low, −back].

1.3. Glottal Fricative

1.3.1. Arguments for Placeless /h/

1.3.1.1. General Agreement

Japanese has a glottal fricative; however, its phonetic status has not yet been examined well. The widely-held view regarding Japanese /h/ is that it is glottal, as "the (voiceless) audible friction is caused in the glottis" (Akamatsu 1997: 97). Also, the following assumptions (made by the majority of researchers) seem to support the idea that /h/ is simply placeless.

(1.43) General consensus about Japanese /h/

a. Synchronically, /h/ becomes [ç] before /i/, and [ɸ] before /u/.

b. Phonetically, the oral posture of /h/ is the same as that of the following vowel.

These two statements may seem to be contradictory, but are generally considered to be compatible. Whatever /h/ would become, the /h/ portions of the signal in both assumptions are different from the following vowel only in terms of what the glottis is doing. Assumption (1.43) suggests that /i, u/ force /h/ to change. A possible phonological analysis would be that /h/ undergoes place assimilation via featural spreading from the coronal gesture of /i/ and the labial effect of /u/,[17] which seems compatible with unified feature geometry (Clements & Hume 1995). In this picture, /h/ is an undergoer of assimilation.[18] If being an undergoer (or non-blocker) of

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[17] One may argue against this analysis, saying that the /u/ of Tokyo Japanese is actually unrounded, and it should not have a labial effect on /h/. But this vowel was historically rounded, and its labiality was retained at least well into the sixteenth century (Martin 1987: 17). The unrounding of the vowel therefore took place sometime after the development of /f/ to /h/.

[18] But see Itô & Mester (2003) for an alternative approach.

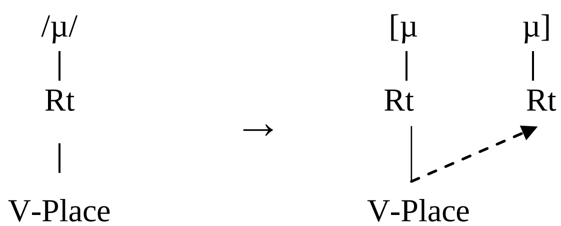
assimilation can be a diagnostic for placelessness (e.g., Paradis & Prunet 1991, but see also de Lacy 2006 for criticism), /h/ can be viewed as placeless. Furthermore, generalization (1.43) has been demonstrated with X-ray tracings of Tokyo Japanese (Uemura & Takada 1990), although this study focuses on only one speaker's speech. Both observations (1.43) generally suggest that /h/ has no independent constriction location.

1.3.1.2. Echo Epenthesis

Japanese loanword phonology provides us with the view that /h/ may be left unspecified in the output of phonology. The default Japanese epenthetic vowel for loanwords is /u/ (e.g., [rakku] 'luck', [kisu]/[kissu] 'kiss', [hoːru] hooru 'hall'); however, after /h/, the epenthetic vowel has the same quality as the vowel preceding /hh/,[19] thus this phenomenon can be interpreted as "echo epenthesis" (e.g., [bahha] 'Bach', [mahha] 'Mach (a measurement of speed)', [gohho] 'Gogh', [eerurihhi] 'Ehrlich', [kehheru] 'Kochel').

Kawahara (2004, 2007) analyzes this as V-place spreading from the preceding vowel, as given below.

(1.44) Echo epenthesis as V-Place spreading



This analysis argues that the intervening /h/ can be transparent and lacks a place node (Steriade 1987a, Stemberger 1993).

1.3.1.3. Japanese Lacks True Pharyngeals

Unlike Semitic and Salish languages, where pharyngeals and pharyngealized consonants exist in the segment inventory, Japanese has never been claimed to have the pharyngeals [ħ, ʕ] in

[19] The condition of the gemination is a different issue. See Arai & Kawagoe (1998).

the phoneme inventory. The Japanese phoneme inventory is given below (from Kubozono & Ota 1998: 116).

(1.45) Phoneme inventory of Japanese

		labial	dental / alveolar	palatal	velar	uvular	glottal	
plosive	voiceless	p	t		k			(Q)
	voiced	b	d		g			
fricative	voiceless		s				h	
	voiced		z					
nasal		m	n			ɴ		
tap or flap			r					
semivowel		w		y				

It is a standard view that Japanese has 15 phonemic consonants. Even in the version of the inventory including allophones (Ota & Ueda 2007: 458-9), the pharyngeal column is left blank. The "Q" beside the table above is traditionally used in Japanese linguistics. The symbol is called *sokuon*, denoting the first half of a geminate, typically appearing before a voiceless stop or a voiceless fricative (e.g., /iQpoN/ 'one bar', /kiQsa/ 'café'). Based on this distribution, Kubozono & Ota (1998) state that Q is a type of consonant, but put it outside the table because geminates can be treated as long consonants and represented without Q (e.g., /kissa/ [kis:a]).

Related to inventories, Rose (1996) argues that whether /h/ is placeless or place-specified is predictable from another aspect of the grammar: the segment inventory. I call this hypothesis the Inventory-driven hypothesis for laryngeals.

(1.46) Inventory-driven hypothesis for laryngeals (Rose 1996: 73)
Laryngeals are specified as Pharyngeal only when pharyngeals or uvular continuants are also present in the inventory of the language; otherwise, they are Placeless.

The laryngeals specified as Pharyngeal are those in Arabic and Hebrew (Semitic) (McCarthy 1994), Nisgha (Tsimshianic) (Shaw 1991), Gitksan (Tsimshianic) (Rigsby 1986), and Iraqw (Cushitic) (Mous 1993), where laryngeals phonologically pattern with pharyngeals and uvulars, and the parallel patternings are explained because laryngeals have a Pharyngeal place feature just like "true" pharyngeal consonants [ħ, ʕ]. This way of featural specification is also supported by the Node Activation Convention (Avery & Rice 1989a, b), which states that a featural node must be activated only when it is contrastive.

According to this view, laryngeals and pharyngeals for languages which have true pharyngeals can be represented below as in (1.47a). In contast, laryngeals for languages without true pharyngeals can be represented without the place node as in (1.47b).

(1.47) Representations with and without true pharyngeals

a. Languages with true pharyngeals

Laryngeals	/ʔ, h/	Pharyngeals	/ħ, ʕ/
	ROOT		ROOT
	|		|
	Pl		Pl
	|		|
	Pharyngeal		Pharyngeal
	|		|
	[+glottal]		[-glottal]

b. Languages without true pharyngeals

Laryngeals	/ʔ, h/
	ROOT

The representations in (1.47a) are based on Lloret (1995: 265) and Lombardi (2001: 29). The contrast between laryngeals and pharyngeals is shown in the value of [glottal]. Lombardi (2001) speculates that the property [-glottal] is highly marked. In the representation in (b), there is no need to specify Pharyngeal because there is no contrast.

Since Japanese has no true pharyngeals, laryngeals do not have to have any place feature, just as in (1.47b). One may argue against this, since Japanese /N/ is a uvular continuant, so it should have a class of Pharyngeal. As expected, uvulars in other languages have been argued to be complex segments having a Pharyngeal node and an Oral node (McCarthy 1991, 1994, Cole 1987, Trigo 1991). But Lloret (1995) states that whether laryngeals have a Pharyngeal node or not is independent of the segment inventory:

> It is crucial to note here that Pharyngeal is necessarily specified in any complex segment, whether the sound system of a language has true pharyngeals or not. The existence of complex segments with a Pharyngeal node has no bearing on whether the Pharyngeal node occurs in laryngeals. (Lloret 1995: 265 [emphasis N.Y.])

She provides evidence that Oromo, which has no true pharyngeal sounds, may have ejectives marked with Pharyngeal, but the glottal stop is placeless, showing the phonological evidence of translaryngeal harmony. Bessell (1992) and Bessell & Czaykowska-Higgins (1992) hold a similar stance.

1.3.2. Arguments Against Placeless /h/

1.3.2.1. Visibility of /h/ Just Like Other Obstruents

This section makes the point that /h/ has some place, based on the parallel behavior of /h/ with other consonants. If /h/ is placeless, /h/ should never be a trigger or target of phonological processes involving place.[20] But in Japanese phonology, many processes target /h/ just like other consonants. What is interesting is the output becomes a labial consonant [b, p, pp]. This alternation is well-known evidence to support that /h/ historically developed from /p/, but here I will bring these examples as an argument that /h/ is not placeless.

Rendaku is a well-known voicing process in Japanese. The voicing applies to the initial consonant of the non-initial member of a compound (see Otsu 1980, Itô & Mester 2003, Rosen 2003, Rice 2005 for the details). Rendaku targets /h/ just as it does the obstruents. Unlike other targeted segments, /h/ shifts to [b] rather than [ɦ]. Thus many researchers posit /p/ for this /h/ as an underlying form.

(1.48) Rendaku targets /h/ to output /b/

a.	yude ‘boiled’	+	tako ‘octopus’	→	yudedako	‘boiled octopus’
b.	ama ‘rain’	+	kaeru ‘frog’	→	amagaeru	‘rain-frog, tree frog’
c.	nihon ‘Japan’	+	saru ‘monkey’	→	nihonzaru	‘Japanese monkey’
d.	mitu ‘honey’	+	hati ‘bee’	→	mitubati	‘honeybee’

[20] This may contradict my earlier statement that being a target of assimilation is a (possible) diagnostic for placelessness. One thing I am implicitly pointing out here is that the ability to be a target of assimilation could be used as either side of the argument.

If /h/ is placeless, morphemes beginning with /h/ as in form (1.48d) should be invisible to the rendaku rule. But rendaku applies to them and shifts /h/ to [b], so /h/ should not be treated as a placeless consonant.

Another source of evidence is the visibility of /h/ for intensive affixation (Kuroda 1979, McCawley 1968, Martin 1952, Poser 1984a, b, Vance 1987: 44-47, Itô & Mester 1996: 24-5, Hirayama 2005). Intensive affixation is a morpho-phonological process that contracts two consonants that straddle two morphemes to produce a geminate. Itô & Mester (1996) calls it root fusion.

(1.49) Root fusion of verbal compounds (Examples from Itô & Mester 1996: 24-5)

a.	but 'strike'	+	toosu 'pass'	→	buttoosu	'continue non-stop'
		+	kiru 'cut'	→	bukkiru	'hack'
		+	hanasu 'let go'	→	buppanasu	'fire (a bullet)'
b.	tuk 'thrust'	+	kakaru 'start'	→	tukkakaru	'plunge'
		+	nomeru 'slant'	→	tunnomeru	'fall forward'
		+	hasiru 'run'	→	tuppasiru	'run without break'
c.	hik 'pull'	+	kaku 'scratch	→	hikkaku	'scratch violently'
		+	saku 'tear'	→	hissaku	'tear apart forcefully'
		+	haru 'tighten'	→	hipparu	'pull, jerk'

A similar root fusion takes place in Sino-Japanese k-stems, but not t-stems (e.g., /gak/ + /kai/ 'society' → gakkai 'learned society').

Itô & Mester (1996: 25) point out that there is a significant difference in the root fusions between Sino-Japanese and Yamato (i.e., native) vocabulary. [21]: In Yamato morphemes, "[v]erb-root-final /k/ triggers gemination of any following [+cons] segment [emphasis N.Y.], not just /k/", thus /h/ should be visible just like any other consonant. But in Sino-Japanese, /h/ as well as other consonants cannot be targeted for k-stem fusion (/gak/ 'study, learning' + /hi/ 'expenses' → gakuhi *gappi 'education expenses'). /h/ behaves like a segment that has place.

[21] It has been claimed that Japanese has a stratified lexicon, which consists of at least Yamato (native), Sino-Japanese, and Foreign strata. See Itô & Mester (1995a, b, 1999, 2003), Ito, Mester & Padgett (1999), Tateishi (2003).

Furthermore, Itô & Mester imply that /h/ is [+consonantal], rather than [-consonantal]. On the other hand, Trigo (1988) assumes glottal segments are [-consonantal], and should get the value [+consonantal] at a later stage and acquire dorsal place at phonetic implementation (sec. 1.1.1.). But if we follow this idea, it is not compatible with the fact that /h/ is targeted in morpho-phonological processes, which should be *before* the phonetic implementation level. Thus /h/, at least the one appearing in this context, must be [+consonantal] in the phonology, and should not be categorized as a placeless segment.

A similar example is adverbial intensifier infixation. This process forms a geminate from the medial consonant of a bimoraic base, and attaches /ri/ (see e.g. Martin 1952: 71, Itô & Mester 1986: 275). This pattern can be generalized as follows: C_1VC_2V-ri becomes C_1VXC_2V-ri (insertion of a moraic segment X), where X is realized as the same as C_2 if C_2 is voiceless, while X is realized as /N/ if C_2 is voiced. Examples are below.

(1.50) Adverbial intensifier infixation (data from Itô & Mester 1986: 275)

a.	pata	'palpitating'	+	ri (adv)	→	pattari
b.	niko	'smiling'	+		→	nikkori
c.	ʃobo	'lonely'	+		→	ʃoNbori
d.	uza	'bored, disappointed'	+		→	uNzari
e.	sinari	'supple'	+		→	siNnari
f.	simi	'quiet, abject, spiritless'	+		→	siNmiri
g.	boya	'vague'	+		→	boNyari
h.	fuwa	'light'	+		→	fuNwari

The words in this list are examples of onomatopoeia, and /h/ is rare in this vocabulary type. But a similar process is attested in Yamato vocabularies, as in /yahari/ → [yappari] 'after all'. More importantly, Itô & Mester (1986) claim that rhotic /r/ is placeless in Japanese, because it is excluded from many phonological processes, and this gemination process is one of them.

(1.51) /r/ cannot be a target of gemination (data from Itô & Mester 1986: 275)

a.	hura	'swaying'	+	ri (adv)	→	hurari	*huNrari	*hurrari
b.	horo	'weeping'	+		→	horori	*hoNrori	*horrori
c.	yura	'swinging'	+		→	yurari	*yuNrari	*yurrari
d.	kara	'drying'	+		→	karari	*kaNrari	*karrari

If we follow the generalization, the intensive morpheme should be realized as /N/, but this option is not permitted. Another option /rr/ is not permitted either. The only possible result is a non-geminated form. This can be seen as evidence that /r/ is placeless in Japanese phonology (see Itô & Mester (1986) for the invisibility of /r/ for palatalization).

This section has shown that /h/ is targeted for rendaku and two kinds of gemination (i.e., intensive affixation and adverbial intensifier infixation). For these morpho-phonological processes, /r/ exhibits a special placeless behavior, while other consonants exhibit behavior consistent with having place. /h/ behaves like the other consonants, not like /r/. That is, /h/ behaves as though it has place.

1.3.2.2. Articulatory Conflict of *hi

The evidence presented in the preceding section suggests /h/ behaves like a consonant having a place. But it does not show which place /h/ could have. This section suggests that the place of /h/ may be pharyngeal.

One way of thinking about assumption (1.43) is that Japanese /h/ shifts to other consonants because of the articulatory conflict between the tongue root and the tongue dorsum. Gick & Wilson (2006) argue that conflicting targets, between tongue root backing/lowering and tongue dorsum fronting/raising, develop crosslinguistically diverse repair strategies. Furthermore, in the well-known languages in which /h/ is pharyngeal, the sequence of /h/ and a high vowel is banned (*hi, *hu). As a response to such a cooccurrence restriction, vowel lowering or laxing typically occurs (for Semitic see McCarthy 1988, 1991, 1994, for English and Salish languages see Gick & Wilson 2006, for Saanich see Bird and Leonard 2009, for Interior Salish see Bessell 1992, for Nisgha see Shaw 1991, for Gitksan see Rigsby 1986, Brown 2008, Yamane-Tanaka 2007, for Oowekyala see Howe 2000, etc.).[22] These phonological patterns should be phonetically grounded, in that certain featural combinations are avoided (Archangeli & Pulleyblank 1994).

One might argue against the idea presented above by saying that both assimilation and cooccurrence restrictions lack empirical grounding, as in Japanese, /h/ historically originated from /p/, which shifted to /ɸ/ and then to /h/ (Shibatani 1990: 166-7; Yamaguchi 1997: 153-4). That said, [hi] and [hu] have never occurred as valid combinations in Japanese history (thus, [ɸi, ɸɯ] > [çi, ɸɯ] is more plausible), so place assimilation could not have happened as a phonetic response to articulatory conflict. However, [ɸ] to [h] occurred elsewhere (i.e., before nonhigh vowels). Why then has the same shift never occurred before high vowels?

Dialectal evidence also supports the articulatory conflict between [h] and high vowels. Shitamachi or 'downtown' speakers (speakers from the eastern part of Tokyo, which is older than the western half of Tokyo) pronounce [ʃi] for /hi/ (e.g., hibachi 'brazier' as shibachi (Vance 1986: 22). Hashimoto (1927) raises philological evidence that this kind of pronunciation already appeared in the beginning of the 18th century in the Kanto area. I have heard some speakers say [ʃiko:ki] for hikooki 'airplane'. The emergence of [ʃi] can be considered as another response to *hi. Vance (1986) generalizes this as a merger of [çi] and [ʃi], which does not conflict with my view. If [h] were pharyngeal, this avoidance would have both phonetic and phonological grounds; that is, articulatory conflict with [i], or "antagonistic" featural combinations (Archangeli & Pulleyblank 1994) between pharyngeals [−high, +low, +back] (SPE: 307) and high vowels [+high, −low, −back].

Therefore, diachronic evidence suggests that the cooccurrence restriction exists over time, and synchronic dialectal evidence suggests that different responses exist, even among speakers from Tokyo.

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[22] In all most of these cases, the repair occurs to a vowel (e.g., /hit-xw/ > [hɛtxw ~ hetxw] 'stand' (vi sg) in Gitksan (Tshimshanic) (Rigsby 1986: 205), but there are cases where the consonant is also repaired. For example, in Saanich (Northern Straits Salish), /iq/ sequences are pronounced with a transitional fricative [ixq]. In Chumburung (Kwa; Niger-Congo), [l] and [r] alternate depending on the advanced/retracted context (see Pulleyblank 2011).

1.3.2.3. Pharyngealization Adjacent to /a, o/

If assumptions (1.43a) and (1.43b) are combined, it becomes unclear whether the trigger for assimilation is (only) high vowels or all vowels. [<u>ç</u>i] has strong palatal friction, and [<u>ɸ</u>ɯ] has lip protrusion; these properties are easily distinguishable from [<u>h</u>e, <u>h</u>o, <u>h</u>a], thus, [h], [ç] and [ɸ] have been established as allophones in Japanese phonology. This implies a phonological asymmetry distinguishing high vs. nonhigh vowels. But neither the auditory judgement or visual impression proves that [h] is the same before all nonhigh vowels. Fine phonetic details, which are sometimes audibly and visibly unclear, may exibit covert contrast [23] in phonological systems (e.g., Kim & Pulleyblank 2009, Li, Munson, Edwards, Yoneyama & Hall 2011, Munson, Edwards, Schellinger, Beckman & Meyer 2010, Goldstein & Fowler 2003, Mielke, Baker & Archangeli 2006).

Moreover, the strong featural affinity between [a] and [h] has been suggested in feature geometry: /a/ should not be categorized either as coronal or labial, but rather a distinct category of pharyngeal (Hayward & Hayward 1989, McCarthy 1988, E. Pulleyblank 1989, Lombardi 2002, Mudzingwa 2010). If it is, it may not be unreasonable to think that /a/ causes /h/ to shift to pharyngeal [ħ] or pharyngealized [h^{ħ}] as well.

If /a/ is pharyngeal, it is more reasonable to think that /a/ causes a shift from /ka/ to [qa] or [ħa]. In fact, there are a few examples to suggest the alternation between [k] and [q, ħ] (or some uvularized or pharyngealized sound). In the casual speech style of old men, /k/ seems to be perceived as [q] or [ħ] before /a/ and perhaps /o/. Examples include /wakatta/ [waqatta, waħatta] ‘understood’, /okotta/ [oqotta, oħotta] ‘got angry’.[24]

The alternation between [k] and [h] is systematically attested in several sub-dialects of the broader North Okinawan dialect (NOJ). For example, word-initial /k/ before /a, o/ in Tokyo Japanese (TJ) corresponds to /h/ in Nakijin dialect. The examples include [<u>ha</u>c’ɴ]$^{\text{NOJ}}$ [<u>ka</u>ku]$^{\text{TJ}}$ ‘to write’, [<u>ha</u>du:]$^{\text{NOJ}}$ [<u>ka</u>do]$^{\text{TJ}}$ ‘corner’, [mu<u>hu</u>]$^{\text{NOJ}}$ [mu<u>ko</u>]$^{\text{TJ}}$ ‘husband’ (Shimabukuro 1997: 358).[25]

[23] Covert features are “features not obviously contrastive based on the surface inventory but that play a contrastive role based on their interaction with constraints” (Kim & Pulleyblank (2009: 568)).
[24] Thanks go to Bryan Gick for communication regarding this topic.
[25] And it is well known that /p/ or /ɸ/ in these dialects correspond to /h/ in Standard Japanese (Shimabukuro 1997: 357). Examples include [p‘ani] $^{\text{NOJ}}$ [hane] $^{\text{TJ}}$ ‘wing’, [p’i] $^{\text{NOJ}}$ [çi] $^{\text{TJ}}$ ‘fire’, [p‘uni] $^{\text{NOJ}}$ [fɯne] $^{\text{TJ}}$ ‘boat’, [p‘ira] $^{\text{NOJ}}$ [hera] $^{\text{TJ}}$ ‘spatula’, [p‘uni] $^{\text{NOJ}}$ [hone] $^{\text{TJ}}$ ‘bone’.

The reason that this shift only occurs with /a, o/ can be ascribed to the inherent pharyngeal property of these vowels – thus [aˤ, oˤ]. In other words, high front vowels [i, e] cannot trigger a [k] to [h] shift, because they do not have pharyngeal constriction.

1.4. What is Instrumentally Tested in This Thesis

The current study uses ultrasound imaging to examine the phonetic implementation of the moraic nasal /N/ and the glottal fricative /h/ of Japanese. The hypothesis I test is given below.

(1.52) Hypothesis

Japanese /N/ and /h/ are specified for place.

This hypothesis is based on my research question about whether /N/ and /h/ are placeless phonetically. These two consonants in Japanese have been argued to be placeless phonologically (see sec. 1.2.1. for /N/ and sec. 1.3.1. for /h/), but their phonetic place of articulation has not been investigated fully in the literature.

In spite of such arguments, the hypothesis that Japanese /N/ is phonetically placeless sounds counterintuitive, since native speakers of Japanese have an intuition that some dorsal constriction is happening during the production of /N/. But it is difficult even for native speakers of Japanese to understand where the constriction is happening. This is especially because the articulation is made at the back of the tongue and is usually not visible, and /N/ occurs only in coda position, where the cue of the place of articulation is relatively weaker than in onset position. The experiments will highlight this perceptually weak position, not only to give confirmation to native speakers' intuition that /N/ has a place, but also to detect where the place of articulation is.

Arguments in favour of placeless /N/ are mostly found in the phonological literature, but no instrumental evidence has been presented in support of this claim. In contrast, opponents of placeless /N/ have tried to make a detailed transcription of the pronunciation, but opinions on where the place is vary, ranging from coronal place to glottal place. Since different claims have been made about Japanese /N/, one may wonder why there is this confusion. It is easy to imagine that the confusion could come from the impressionistic transcriptions of Japanese /N/ – the transcribers may be biased. If this is the case, some objective criterion for judgement is needed.

The second hypothesis is about Japanese /h/. Unlike /N/, there is a general consensus that /h/ is placeless. But this consensus lacks qualitative and quantitative instrumental evidence to support it. Furthermore, there has been a debate over the ambiguous status of glottal consonants between being placeless or pharyngeal, but Japanese /h/ has not been discussed in this context. In light of the evidence in sec. 1.3.2. - i) visibility of /h/ in morphophonological processes, ii) avoidance of articulatory conflict of *hi, and iii) pharyngealization adjacent to /a, o/ – there remains a possibility that Japanese /h/ also has an independent place, which is pharyngeal.

In order to test these hypotheses, I use ultrasound technology to observe how the tongue moves in the production of these sounds relative to the adjacent vowels. I will present data from six native speakers of Tokyo Japanese. Data from multiple speakers are necessary because not much attention has been paid to individual variation. In the end, the individual variation will prove interesting in itself.

In order to make the hypothesis refutable, I have set up a series of questions that we may answer through the experiments, and which may establish the properties of place. Following Browman & Goldstein (1986 et seq.), I assume that the presence or absence of "place" is the presence or absence of an articulatory gesture, with the Tongue Body as the tract variable and a constriction degree (CD) and a constriction location (CL) as its parameters. In this dissertation, I will treat CD as corresponding to the vertical dimension of the tongue and CL as corresponding to the horizontal dimension of the tongue. Therefore, the first question to ask is whether /N/ and /h/ exhibit a distinct CD (chapter 2, 3), and if so, to then investigate CL (chapter 4). The flow of questions is schematically shown below.

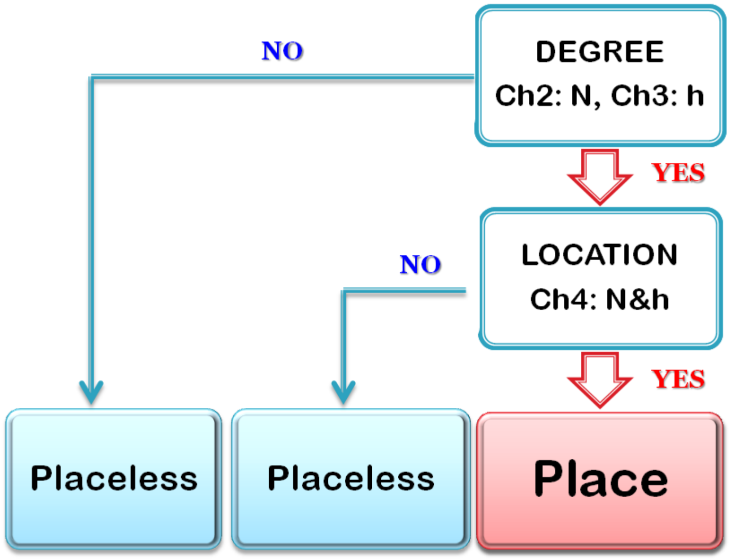

Figure 1.5. Procedures to find place for segments

As shown in the righthand column, if both CD and CL are observed, a place can be determined for the segment.[26]

Data will be discussed for the individual speakers as well as the group of speakers. This is because my study is in part about undescribed individual variation. Variation study leads us to pose linguistically significant questions: Is variation random? What is the source of variation? How much variation is permitted among speakers of the same dialect? Investigation into individual variation can give new living data to the existing literature, which various researchers can access and observe.

[26] In this step-by-step procedure, two kinds of placelessness may be implied: (i) placelessness that has no CD and no CL, and (ii) placelessness that has CD but no CL. These two emerged based on the conception that CL should never be activated without the specification of CD. But no empirical argument excludes another kind of placelessness: (iii) the case having CL but no CD. Glides [j, w] could fit in this category in that these glides may allow greater variability depending on the height of the preceding vowel (e.g., [aj] vs. [ij], [aw] vs. [uw]), although CL seems to be quite obvious. In contrast, Nevin & Chitoran (2008) suggest they have an independent CD but CL consists of two places – [j] has [Dor, Cor] and [w] has [Dor, Lab], which might be taken as an argument that these glides may be type (ii).

1.5. Roadmap of this Thesis

The remainder of this dissertation is organized as follows. Chapter 2 presents the experimental results for the Japanese moraic nasal /N/, showing that every speaker has a place somewhere, at least phonetically. Chapter 3 discusses the glottal fricative /h/, showing that whether it has a place or not depends on the speaker. Chapter 4 compares /N, h, k/, focusing on the location target and the variability of /N/ relative to [h] and [k]. Chapter 5 discusses the theoretical implications and remaining issues, and concludes the discussion.

Chapter 2 **The Japanese Moraic Nasal**

2.1. Introduction

This chapter aims to answer the question of whether the Japanese moraic nasal is placeless or not. Multiple case studies of Tokyo Japanese are conducted to observe phonetic and phonological variations across speakers. The experimental results suggest that Japanese moraic nasal is specified for a place for all speakers.

2.1.1. Placeless vs. Place-specified

This chapter discusses the phonetics and phonology of the moraic nasal in Japanese. The goal of the chapter is to answer the question of whether or not the Japanese moraic nasal is phonetically placeless.

The generative phonetics approach assumes a direct relation between phonological representation and phonetic implementation (Pierrehumbert 1980, Cohn 1990, 1993, 2003, Keating 1988, 1990); whether or not the feature value is specified in the phonology is reflected in the phonetic signal. In the phonology literature, the use of the symbol /N/ for the Japanese moraic nasal is widespread, indicating that this nasal is considered placeless. The evidence most frequently cited for placelessness is predictability, debuccalization and high articulatory variability (see sec. 1.2.1.3.). Thus, from the assumption of the direct mapping of generative phonology, it is plausible to assume that if /N/ is phonologically placeless, it should be phonetically placeless as well.

In the phonetic literature, however, not just the transcription but the description varies. Based on X-ray photographs, the place of Japanese /N/ has been described as uvular (Nakano 1969: 220, Naito 1961: 118, Vance 1987), and as velar or uvular (Uemura & Takada 1990, Uemura 1997a). What is especially interesting is that the transcription of /N/ shows more variation when it is before a vowel. The majority claims that it is a debuccalized /N/, or a nasalized vowel, but there is no agreement about where the quality comes from, or how it is realized. Previous articulatory studies of Japanese /N/ have been inconclusive as well, each being limited to a single speaker and lacking quantitative measurements. The current study uses ultrasound to examine the phonetic implementation of /N/ adjacent to /a/, in testing the hypothesis that Japanese /N/ has a place specification.

In this first experimental chapter, the test focuses on whether /N/ has a distinct CD or not. If a CD independent of the surrounding context is found to exist for /N/ in this chapter, then this will raise the question of CL, which will be discussed in a later chapter (chapter 4).

The structure of this chapter is organized in the following way: Section 2.1.2. presents predictions of the experimental results about the tongue contour of /N/ in a VCV sequence, based on my hypothesis that /N/ has a distinct CD; section 2.2. explains the methodology for the ultrasound experiment; section 2.3. presents the results of the experiment; section 2.4. is the discussion; section 2.5. is the conclusion.

2.1.2. Predictions

In relation to phonetic experiments, the two competing views – the placeless vs. the place-specified hypothesis for /N/ – would make different predictions. From the standpoint of generative phonetics, there is a direct relation between phonological representation and phonetic implementation (Pierrehumbert 1990, Cohn 1990, 1993, 2003, Keating 1988, 1990, Chitoran & Cohn 2009); i.e., whether or not the feature value is specified is reflected in the phonetic signal.

The predictions of generative phonetics can work in both directions between phonetics and phonology: particular types of *phonological* patterning predict a particular *phonetic* implementation and particular *phonetic* patterns predict the presence or absence of a feature *phonologically*. Because the predictions are bidirectional in this way, we can detect whether or not the feature is specified based on the phonetic evidence. Thus, if /N/ has an interpolative quality in the trajectory from the first /a/ (henceforth “a1”) to the second /a/ (henceforth “a2”) in the sequence /aNa/, it should be placeless; however, if it has a target that is distinct in constriction degree from both a1 and a2, a place has to be specified for /N/.

The question is, with the use of ultrasound data, what must be shown to argue for an interpolative quality, and what must be shown to argue for an independent place feature. This point will be discussed below. The representation in (2.1) illustrates the case where the place feature of /N/ is unspecified in the phonology.

(2.1) Placeless /N/ in output of phonology

```
  a      N      a
  |             |
V-pl          V-pl
  |             |
  α             α
```

Figure 2.1 below shows the corresponding phonetic implementation. Since I will test placelessness by examining the physical movement of the tongue, I will show the predicted phonetic implementation by way of schematic representations of midsagittal tongue tracings. In the figures in this section, the solid red line denotes /N/, the broken blue line denotes a1, and the dotted green line denotes a2.

The essence of a supposedly placeless /N/ would be its interpolative nature. If /N/ lacks a featural value for place, its physical position should simply be somewhere on the trajectory between V1 and V2. If V1 and V2 are significantly different and located apart from each other, as shown in Figure 2.1, then the overall line for /N/ should appear between the lines for a1 and a2.

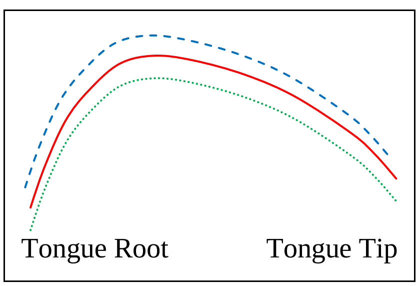

Figure 2.1. Predicted placeless /N/ in output of phonetics

During the temporal span of the segment, being closer to V1 would result in a value more like V1's, and being closer to V2 would result in a value more like V2's. So, assuming a continuous transition, at the midpoint of the temporal span of /N/, the tongue contour should be roughly centered between V1 and V2. Thus the sandwiched pattern above is the expected interpolation pattern, since /N/ should be in the intermediate position in the trajectory from V1 to V2.

The representation in (2.2) illustrates the case where the place feature of /N/ is specified in the phonology.

(2.2) Place-specified /N/ in output of phonology

a N a
| | |
V-pl C-pl V-pl
| | |
α β α

The figures below show the corresponding phonetic implementation. Figure 2.2 is the case where V1 and V2 are roughly the same, and Figure 2.3 is the case where V1 and V2 are significantly different.

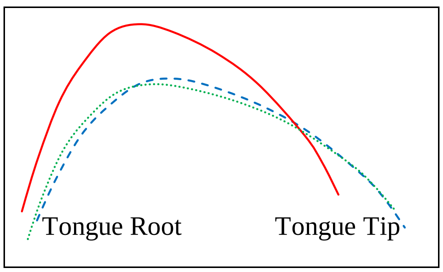

Figure 2.2. Predicted place-specified /N/ in output of phonetics: when V1=V2

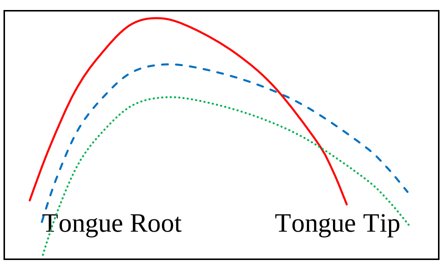

Figure 2.3. Predicted place-specified /N/ in output of phonetics: when V1≠V2

If /N/ has an independent place feature, the contour of /N/ should be significantly different from both V1 and V2, and at least some part of the tongue should be outside both V1 and V2. Both figures show that /N/ retracts the tongue root and/or dorsum compared to the adjacent vowels. Whether V1 and V2 are the same or different, this point would not be affected. A digression from both V1 and V2 is an important diagnostic for having an independent constriction gesture, because the digression shows the segment resists being interpolated between the adjacent vowels.

However, having a place is not limited to the cases above. Even if the line of /N/ is not really outside of the two vowels, some cases can be considered as being place-specified. One of those cases is assimilation to the V on either side, as below. /N/ appears to be identical to either V1 (as in Figure 2.4(a)) or V2 (as in Figure 2.4(b)).

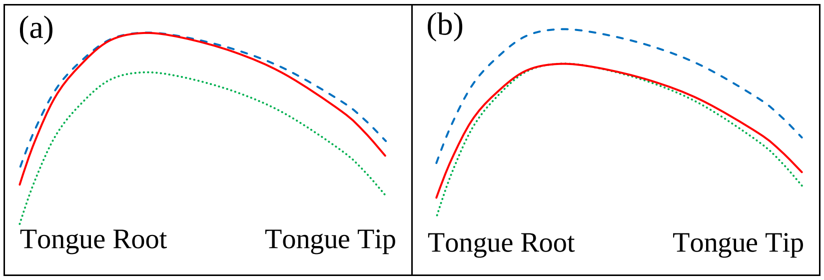

Figure 2.4. Predicted place-specified /N/ in output of phonetics: assimilation to one V

This could happen when /N/ is temporally overlapped with either of the vowels, which is called 'temporal sliding' of gestures (Browman & Goldstein 1992b).[27] So depending on the relative timing, the tongue position for /N/ could be closer to V1 or V2, resulting in a statistically insignificant difference between /N/ and V1 or /N/ and V2.

In another case, none of the pairs between V1, V2 and /N/ shows any significant difference, as in Figure 2.5.

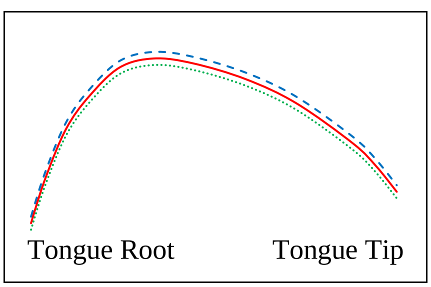

Figure 2.5. Predicted place-specified /N/ in output of phonetics: Assimilation to both Vs

Since /N/ completely overlaps with both V1 and V2, /N/ should share the same feature with V1 and V2 in the output of phonology. Totally assimilated segments such as this may allow

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[27] For example, in English, when N occurs without any oral constriction, as it often does in "ca<u>n</u> we", the durational center of the N overlaps with V1.

ambiguous interpretations of /N/ between being place-specified and being placeless. (See sec. 3.1.2. for details.)

Phonetic signals predict certain types of phonological representations. Below I consider more cases of how phonetic signals are mapped onto phonological representations, where the same indices indicate that the segments are associated to the same set of features; I assume here that multiple linking must be strictly local (Archangeli & Pulleyblank 1994, Gafos 1996[1999]: 77–81, Ní Chiosáin & Padgett 2001; see Archangeli & Pulleyblank 2007 for issues of locality).

(2.3) Phonological representations based on significant differences in phonetics

	Phonetic Realization	Phonological Representation
a.	All three are the same	(i) V_i C_i V_i (ii) V_i C V_i
b.	V1, V2 are the same; C is different	V_i C_k V_i
c.	All three are different	(i) V_i C_k V_j (ii) V_i C V_j
d.	V1 and C are different from V2	V_i C_i V_j
e.	C and V2 are different from V1	V_i C_j V_j

Since the current experiment uses words where V1 and V2 are phonologically the same, the reasonable realizations should be either (2.3a) or (2.3b) above. First, if all three segments are phonetically (and statistically) the same, as in (2.3a), then a possible phonological representation would be that each segment shares the same feature by assimilation (place-specified), as in (i), or C is unspecified and allows interpolation, as in (ii). Second, if V1 and V2 are different from C, then C should have a feature, as in (2.3b).

On the other hand, if V1 and V2 are statistically different despite the fact that they are phonemically the same, then the possible representations would be one of (2.3c-e). Statistical results of phonetic realizations give us an idea about whether the distributions of the segments are the same or different, but tell us nothing about how different the physical locations of those segments are. Even if they share the same phoneme, they could be statistically different. If the situation is like (2.3c), the choice between (i) and (ii) in (2.3c) is made based on whether C diverges from the linear interpolation between the two vowels: If it diverges, a feature is specified, but if it does not it is unspecified. The cases (2.3d, e) are types of assimilation: If the two adjacent segments are different from the vowel on the other side, that vowel must have a different feature from the other two segments.

Assimilation cannot be a type of placelessness, because the assimilated C has a specific place feature. Keating (1988) clearly illustrates this point. Figure 2.6. below illustrates the difference in acoustic signals between a carryover effect [1], interpolation [2], and an anticipatory effect [3]. The instrumental evidence of such a contrast is suggested in Keating (1988): In Russian /x/, there is no lexical contrast between velarized versus palatalized dorsal fricatives. Thus [back] can be thought as underspecified underlyingly. But the shapes of F2 show some difference between /ix̱a/ and /ax̱i/ in Russian. The former shows a continuous transition (as in [2] below) during /x/, while the latter shows the steady state of F2 (as in [3] below) throughout the duration of /x/.

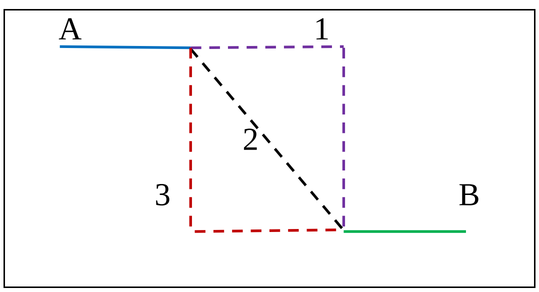

Figure 2.6. Carryover effect, interpolation, anticipatory effect

Keating suggests the steady state of F2 of [x] in /axi/ is a piece of evidence that [-back] comes from segment B through a contextual rule later in the derivation. Different from interpolation, an anticipatory effect fills the unspecified value of [back] of /x/ with the same value as that of B, which can be seen as the result of phonological assimilation. The same reasoning applies to SS-ANOVA data showing tongue configuration. But the problem is unlike that of the spectrographic data; the current ultrasound data shows only the midpoint of each segment, so the overall trajectory of /N/ - how the tongue configuration changes from the starting point of V1 to the end point of V2 - is not totally clear. But it should be safe to assume that if /N/

is interpolative, then the midpoint of /N/ should correspond to approximately the midpoint of [2], while if it is assimilation, the midpoint should be approximately the midpoint of [1] or [3].[28]

Thus, if the segment in question is assimilation-type, the place and degree should be approximately the same as either A or B. Since A and B clearly have a place target, if the segment in question is statistically the same as A or B, it should also have a place target. What matters here is whether the segment has a place target or not.

2.2. Methodology

2.2.1. Subjects

Seven native speakers of Standard Japanese participated in the experiment: 5 females and 2 males, ranging from their early 20s to late 30s. All speakers had spent their lives in Tokyo or Kanagawa, at least until they graduated from high school, and were undergraduate or graduate students at the University of British Columbia at the time of the experiment. One subject's data was not used for analysis, because the subject had an operation due to a temporomandibular joint disorder which may have affected her speech production. The participants whose data were used included 4 females and 2 males as given in Table 2.1 below. Since this is a multiple case study of individual variation, I list some additional information including the areas where they have lived.

[28] Zsiga (1997) also argues that assimilation and coarticulation should have different representations; featural spreading for the former, and gestural overlap for the latter. The underlying idea in splitting the two similar phenomena is that there is a phonology-phonetics mapping system, through which the discreteness and gradience in signals should be mapped onto the representations.

Table 2.1. Participants' sex, age, residences

Initial	Sex	Age	Residences
HS	F	late 30's	0-3; Tanashi (currently Nishi-Toyo) city, Tokyo, 3-13; Hooya (currently Nishi-Toyo) city, Tokyo,13-26; Higashi-kurume city, Tokyo,26-35; Toronto, Canada, 35-39; Vancouver, Canada
AM	F	early 30's	0-19; Odawara city, Kanagawa, 19-22; Sōka city, Saitama, 23-27; Odawara city, Kanagawa, 27-29; Yokohama city, Kanagawa, 29-31; Odawara city, Kanagawa, 31-; Vancouver, Canada
TT	M	late 20's	0-21; Yokohama city, Kanagawa, 21-27, Shinjuku-ku, Tokyo, 27-28; Vancouver, Canada
YS	F	late 20's	0-19; Shinjuku-ku, Tokyo,19-22; Sapporo-city, Hokkaido, 23-28 Vancouver, Canada
KK	M	early 20's	0-4; Tama city, Tokyo,4-14; Hachioji city, Tokyo,15-20; Setagaya-ku, Tokyo,20-21; Minato-ku, Tokyo, 21-22; Vancouver, Canada
MK	F	early 20's	0-4; Setagaya-ku, Tokyo,4-7; Paris, France, 7-21; Setagaya-ku Tokyo, 21-22; Vancouver, Canada

The purpose of this experiment was not told to the subjects. They were paid for their participation.

2.2.2. Stimuli

2.2.2.1. Selection

All stimuli consisted of pseudo words. Real words were not used, because the phonetic/phonological environments of existing words are too diverse to be controlled to meet the criteria of the experimental purpose. All words were made as uniform as possible, so that the potential influence that diverse phonetic, phonological, and morphological factors may cause could be avoided.

The target word used for the analysis is in (2.4a), and distractor words are in (2.4b):

(2.4) Stimuli of /N/ Series

a. Target Word: aNa
b. Distractor Words: aNi, aNe, aNo, iNa, iNe, iNo, uNe, uNo, iNi

I will describe how I selected /aNa/ as the target word. First, /N/'s target may be masked if V1 and V2 are not identical. In the pilot study using /aNi/, for example, we found no clear target effect for /N/ was obtained. A target effect is a prominence of a certain gesture that stands out in the context, or "movement of the tongue away from the position […] between the V1 and V2" (Browman & Goldstein 1994: 41). Below is the average tracing for /aNi/ for talker TT.

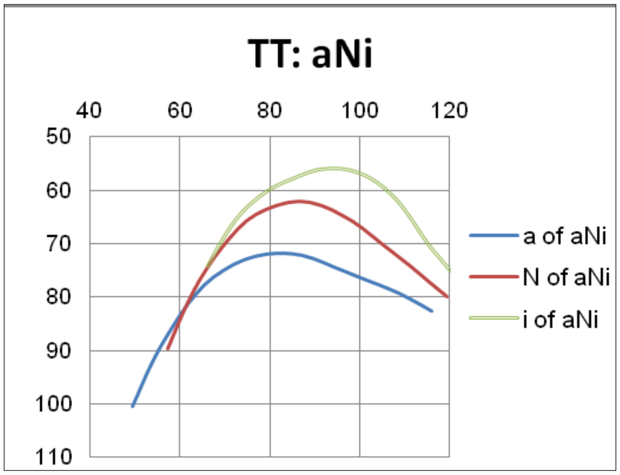

Figure 2.7. TT aNi: Average tracing

The overall tongue contour of /N/ is between /a/ and /i/, suggesting that /N/ is in a continuous transition from /a/ to /i/. Thus in the graph, the intervening /N/'s height seems to be in the mid height, and its backness seems to be in the center, which seems to show an interpolative quality, suggesting the /N/'s features should be unspecified, as we saw in chapter 1, or transcribed as a nasalized vowel [ṽ].[29] But with this evidence, it is premature to draw a conclusion that this segment is targetless, because this constriction degree and location may have coincidentally fitted to this apparent neutral position, due to the opposite values of height and backness of the /a/ and /i/. In order to confirm that this seemingly interpolative trait is not accidental, we need to look at the implementation of /N/ in other environments as well.

According to Browman & Goldstein (1994), the realization of schwa is different depending on the context, and the trait of targeted schwa is clearly attained when it is surrounded by identical vowels rather than by different ones:

[29] Such a transitional nature of N is also seen in the acoustic results of Nakaoka & Muraki (1990: 173), where Ns in /kaN.i/ 'easiness', /naN.i/ 'which rank' show mutually dependent formant transitions.

> […] schwa cannot be treated simply as an intermediate point on a direct tongue trajectory from V1 to V2. Instead, there is evidence that this V1-V2 trajectory is warped by an independent schwa component. The importance of this warping can be seen, <u>in particular, in utterances where V1 and V2 are identical</u> (or have identical values on a particular pellet dimension). For example, returning to the utterance /pipə'pipə/ in […], we can clearly see (in MX, MY, and RX) that <u>there is definitely movement of the tongue away from the position for /i/ between the V1 and V2</u>. This effect is most pronounced for /i/." (Browman & Goldstein 1994: 41 [emphasis N.Y.])

This suggests that the target effect of schwa is most visible when flanked by /i/ on both sides, because compared to other vowels, /i/ is the furthest from schwa.

This suggests that for the experimental target words, the flanking vowels should be identical, and should be the one located articulatorily farthest from the target of /N/. In the current ultrasound experiment, I chose /a/ for the vowel that should sit next to /N/. But why does it have to be /a/?

According to Browman and Goldstein (1986 et seq.), the CD (constriction degree) target can be divided into several categories – [closed], [critical], [high], [mid], and [low]. Stop consonants are [closed], fricatives are [critical], and vowels are categorized as one of [high], [mid] or [low] according to their height. The CD of /N/ can be either [closed] (if noncontinuant), [high] (if a glide, or high back nasal glide) or [mid] (if approximant, or mid back nasal glide), depending on how /N/ should be labeled for the consonantal class. Among the consonantal classes, [closed] (noncontinuant) is not really accurate, because there is a general consensus that Japanese /N/ has no complete closure. The CD of /N/ therefore is more likely to be [high] (glide) or [mid] (approximant). From this point of view, high and mid vowels should be avoided as the flanking vowels of VNV target words, because the CD of high/mid vowels and the CD of /N/ may be so close that the oral constriction of /N/ could be masked by the gesture of the vowels. In fact, it has been recognized that a nasal consonant patterns exceptionally when it is adjacent to a high vowel. Giriko (2006) analyzes the word-final /N/ after /i/ as extrametrical/invisible to the mora count. For example, loanwords ending in /iN/ show exceptional unaccented patterns contrary to McCawley's (1986) prediction (e.g., [se.ku.re.ʧiN], *[se.ku.ré.ʧiN], 'secretin'; [sak.ka.riN], *[sak.ká.riN], 'saccharin'; [iN.su.riN], *[iN.sú.riN] 'insulin') Another example is utterance-initial /u.m-/. /u/ before /m/ can alternate with /N/, as in the words /**u**ma/ → [**N**ma] ‘horse’, and /**u**me/ → [**N**me] ‘plum’ (Martin 1952: 13). These facts suggest that the CD of /N/ is more likely to be [high], and choosing a high vowel as a flanking vowel to /N/ is not appropriate for us to see the target effect.

If /N/ is [high], the CD should be most conspicuous when surrounded by [low] vowels. [30] Uncontroversially, /a/ is the only [low] vowel among Japanese vowels (see Uemura 1997a for the relative tongue position of each vowel). It is expected that the environment of /a/ will make /N/’s target, if any, stand out most clearly.

One may wonder why intervocalic /N/ rather than word-final /N/ was selected for measurements, with contemplation that word-final /N/ might be more stable. In the pilot study comparing word-final /N/ and intervocalic /N/, it was found that 4 out of 6 speakers have larger variability in word-final /N/. How the articulatory variability should be measured has no easy answer, because in statistics there are several different metrics to examine the variability/variance – namely, standard deviation, inter-quartile range (IQR),[31] and the f-test. In general, the range, inter-quartile range and standard deviation can be indicative of variability. The range is not used here, because if the dataset has some outliers, then it will result in a range that is not typical of the dataset. In order to reduce the problems caused by outliers, the inter-quartile range, which considers the variability within the middle 50% of the dataset, is more appropriate than the range. The standard deviation takes every value in the dataset and determines how it varies from the mean. So far there is no decisive argument leading me to choose only one of these measures of variability, rejecting the rest of them.

Finally, concerning the choice of intervocalic position, I would just note that the word-final /N/ is less stable than word-internal /N/. Furthermore, the source of the variability for this position is not clear; especially if it is utterance-final, lip closure may be involved, and

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[30] It would have been probably best to compare /N/ with the articulatory setting of each speaker. But when the articulatory setting is not available in the measurement, [a] would be the best choice. The relatively low position of the tongue (similar to [a]) as part of Japanese articulatory settings was confirmed in the ultrasound study by Wilson, Horiguchi & Gick (2007). Thanks to Alexei Kochetov for pointing out the relevance of the articulatory setting.

[31] See http://www2.le.ac.uk/offices/careers/ld/resources/numeracy/variability, which says “The inter-quartile range provides a clearer picture of the overall dataset by removing/ignoring the outlying values. Like the range however, the inter-quartile range is a measure of dispersion that is based upon only two values from the dataset. Statistically, the standard deviation is a more powerful measure of dispersion because it takes into account every value in the dataset.”

interspeech posture or rest position may contribute to the variability. Since measurements of these factors are outside the scope of my thesis, I focus on intervocalic /N/.

2.2.2.2. Instructions

Stimuli were presented in the form of a reading list. All stimuli were randomized, and 14 blocks of the same set with different orders were created. The list was printed in katakana letters, which are conventionally used for loanwords in Japanese orthography. This is because participants were told that they were going to read hypothetical place names in foreign countries. Each page consisted of 4 blocks of words at maximum, and the total was 4 pages. The actual reading list is in Tables A.1. - A.4. in Appendix. All words in the 1st and the 14th blocks, and the first word and the last word in each block, were not used for the measurements, in case their articulations may not be the same.[32]

Subjects were given the papers and told that these are hypothetical place names in foreign countries. They were asked to imagine that they have traveled to these places, and to read them at a natural rate as if they were talking about the place where they have been to their friend. Subjects were also told to read all the words with initial accent.

Before the recording session, we conducted a practice session so that the subjects could get familiarized with the words and the accentuation. In this session, they were asked to read out the list, and if subjects made a mistake in accentual patterns, they were corrected.

Although the locus of the accent of loanwords is not completely predictable, there are reasons that I instructed subjects to put the accent on the initial syllable across all the tokens used in this experiment. First, loanwords have a tendency to follow the so-called 'antepenultimate rule' (McCawley 1968), which assigns an accent on the syllable containing the antepenultimate mora, or the third mora from the end of word (e.g., [ku.ri.sú.ma.su] 'Christmas', [ba.do.mín.toN] 'badminton'). Second, Kubozono (2006) observes that heavy syllables tend to attract accent (cf. the weight-to-stress principle (Prince 1990)). Third, according to Kubozono's (2006) survey of the accent patterns of loanword nouns across different syllable types, i) 96% of trimoraic words are initial-accented, irrespective of their syllable structure, ii) the frequency of the initial accent among HL (H=Heavy syllable, L=Light syllable) words (325 words) is 100%. The target words

[32] In our experience, subjects often show anomalous articulatory patterns around the beginning and/or the end of the word list.

used in my experiment are HL (e.g. aN.a), so initial-accentedness would be the most natural pattern from any of these views.[33]

In this way, the accent pattern was kept consistent so that we could avoid the potential effect on the place of articulation that may come from tone differences. Phonologically speaking, a certain phoneme should have the same tongue position whether it is low tone or high tone. However, it could be different phonetically. Tronnier (1996: 122) reports, in the study of nasals in Osaka Japanese, that a greater degree of anticipatory nasalization is present if the vowel preceding the nasal is accented: In examples such as V'N (accented) compared to VN (unaccented), the velum lowering starts earlier, or the amount of velum lowering is larger. It is not clear how the timing and the amount of velum lowering could affect the place of articulation, because the velum and dorsum are usually assumed to function independently.

I have shown that all the tokens were initial-accented in my experimental setting, so that there is no pitch difference that might affect constriction degree and constriction location.

2.2.3. Procedures

2.2.3.1. Recording to Saving

The recording was conducted in the ISRL [Interdisciplinary Speech Research Laboratory] at the University of British Columbia. The ultrasound used was an Aloka SSD-5000 machine with a UST-9118 endo-vaginal 180° electronic curved array probe. The frame rate of the ultrasound system is the North American standard 29.97fps. A Sennheiser MKH 416 P48 super-cardioid short shotgun condenser interference tube microphone stood at an appropriate distance. Subjects sat on an ophthalmic examination chair (American Optical Co., model 507-A) with a 2-cup rear headrest. Water-soluble ultrasound gel was applied to the head of the ultrasound transducer. The transducer was fixed around 90 degrees for every subject, and put against her/his neck above the larynx. The rear headrest was adjusted to hold each subject's neck, but a head stabilizer was not used (see Gick, Bird & Wilson 2005 for issues regarding head stabilization, data presentation and control of the ultrasound experiment). Both visual and acoustic data were recorded onto iMovie,

[33] As predicted, subjects read most of the words with initial accent voluntarily when they saw the reading list, but two subjects read a few HL words as unaccented. The unaccentedness may have come from the emerging tendency of making accented patterns become unaccented (cf. Tanaka 2001). But once those subjects were instructed to read the words with initial accent, they had no trouble in doing so and fixed it right away.

running on a Macintosh computer. The movie clips, which were recorded onto iMovie, were converted to DV files.

2.2.3.2. Making Still Images

Still images of vowels and consonants were made using Final Cut Express ver. 1.01, and saved in JPEG format. It is conventional in lingual ultrasound research (Gick & Wilson 2006, Gick, Wilson, Koch & Cook 2004, Gick, Pulleyblank, Campbell & Mutaka 2006, Davidson 2005, 2006a, b, Bernhardt, Gick & Bacsfalvi 2005) to take the video frame at the midpoint of a segment for a still image, so I followed suit. Another option is to take the maximum constriction point (see Namdaran 2006: 36 for examples), but I did not take this option for the following reasons. First, I had not made any measurements of the rest position which can be compared to the constriction point. Second, the maximum constriction point may be detected if we can obtain an accurate contour of the palate. The contour of the palate is visible in images when the subject swallows water. However, I could not obtain an accurate palate contour from the images. Third, it is easy to judge when the maximum constriction is made for [kk] because it has an oral closure period, but it is difficult for [hh] and /N/ because there is no closure. Furthermore, the closure of [k] happens closer to the following vowel, which does not correspond to the *moraic* position that I am trying to compare across consonants. In other words, it remains unclear how much it would make sense to compare /kk/ in nonmoraic position and /N/ in moraic position. [34]

2.2.3.3. Measurements

There are several ways to measure the tongue surface; I used EdgeTrak (Stone 2005, Li, Kambhamettu & Stone 2005a, b, Parthasarathy, Stone & Prince 2005), and the analysis was done using smoothing spline ANOVAs (henceforth SS-ANOVAs) in R (R Development Core Team 2011) (cf. Davidson 2006a, b).

The procedure of the analysis follows Stone (2005), with some modifications. It is known that SS-ANOVAs work well with data from Palatoglossatron (Baker 2005),[35] but not so well for

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[34] It is not known how much difference exists between the maximum constriction point and the midpoint (however, see Gick 1999 for gestural reduction in codas, compared to onsets). If there is no significant difference between them, there will not be any problem in comparing the data on the midpoint and the data on the maximum constriction point. But this has to be future research.

[35] Palatoglossatron has grids whose several angles are already set for measurements. The center of the grids do not match with the center of the probe in the ultrasound images we have created in our lab. So for the images to be fit

the data generated by EdgeTrak. For example, Edgetrak generates images that are horizontally reversed from the ultrasound image. We solved such problems by changing the contents of the R script. The most serious problem is that the default number of points of a tongue contour in Edgetrak is 100, but R cannot process the data when it has 100 points. Thus we changed it to 30 at the stage when we exported the .con file (a text file that contains a set of xy coordinate points for each contour). In the final stage of data processing, the pixel values of the x-axis and y-axis of 30 points are automatically saved in a .con file. The .con files were converted to Excel files and reformatted for R text, and pasted to text files so that the SS-ANOVAs could run.

The tongue surface traced by EdgeTrak appears in red dots below.

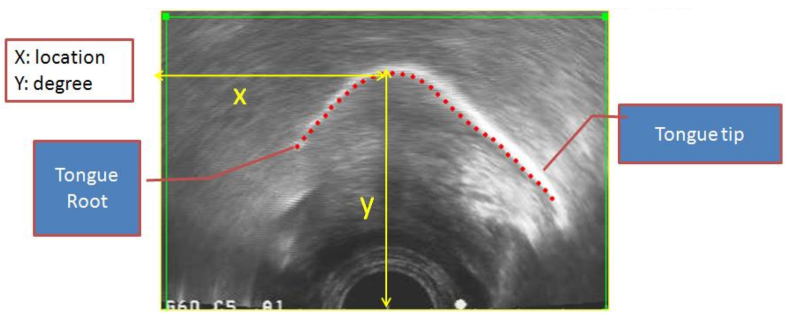

Figure 2.8. Measurement points in EdgeTrak

SS-ANOVA was adopted as the presentation method to show the overall tongue surface for the following reasons: First, in graphical plots of the tongue surface, such as those made using Excel, the comparison of peak point or global shape is possible, but this presentation gives us no information about which *regions* of the tongue are different from each other. Furthermore, with SS-ANOVA, the significant difference between two tongue contours is plotted as the area where the dotted lines which indicate the 95% confidence interval do *not* overlap.[36] Thus, the graphs already incorporate statistical results.

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and measurable, one end of the images would have to be cropped, and another end would have to be added appropriately. This can be done by MATLAB. As EdgeTrak does not have pre-set grids, such a procedure is not necessary.

[36] The non-overlapping area may be measured with an areal measurement tool. This kind of measurement may be useful if you would like to compare the size of constriction across segments.

2.2.4. Analysis

Once SS-ANOVA graphs were obtained, I placed red vertical lines to mark where the significant difference between two lines starts and ends. An example is given below.

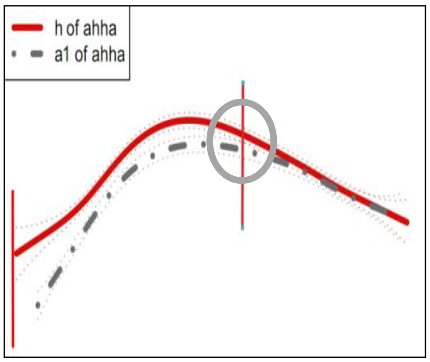

Figure 2.9. Example of a line demarcating a significantly different area

The left-hand side shows the tongue root, and the right-hand side shows the tongue tip. The significant difference is observed roughly from the anterior tongue dorsum all the way to the tongue root, as marked with vertical lines. In this case, the area is roughly 50 mm in length.

Below is a magnified image of the circle drawn in Figure 2.9. The vertical red line is inserted manually where the significant difference starts: The left-hand side shows a significant difference while the right-hand side does not.

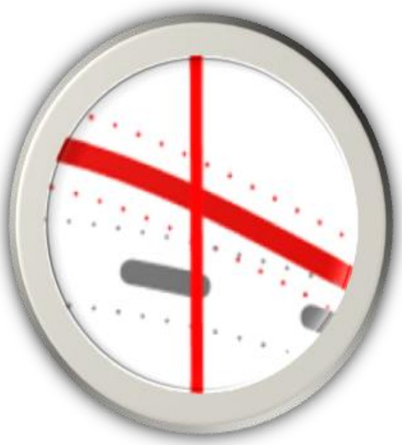

Figure 2.10. Boundary between the area of significant difference (on the left) and the area without significant difference (on the right); note the intersection of the fine red and gray dotted lines.

As the fine dotted lines surrounding the thicker lines show the statistically possible variation, if the dotted lines do not overlap, the two lines are significantly different. The horizontal red line shows the /h/ of /ahha/, and the horizontal gray line shows a1 of /ahha/. The vertical red line indicates the cut-off point between the non-overlapping area and the overlapping area: On the left-hand side, the dotted red lines and the dotted gray lines do not overlap, while on the right-hand side they do overlap.

2.3. Results

It is important to have a general image of what kind of movements the tongue is creating during the sequence /aNa/. Some native speakers of Japanese have an intuition that /N/ has independent constriction degree; x-ray photographs of this sequence in Uemura & Takada (1990) are consistent with this intuition, but that study was limited to a single subject. So the general question is whether this intuition is right in general for native speakers of Japanese.

The detailed measurements will be presented later, but below I will show the average tracings of 12 repetitions of /aNa/ by 6 native speakers of Tokyo Japanese. In these images, the tongue tip is facing to the right.

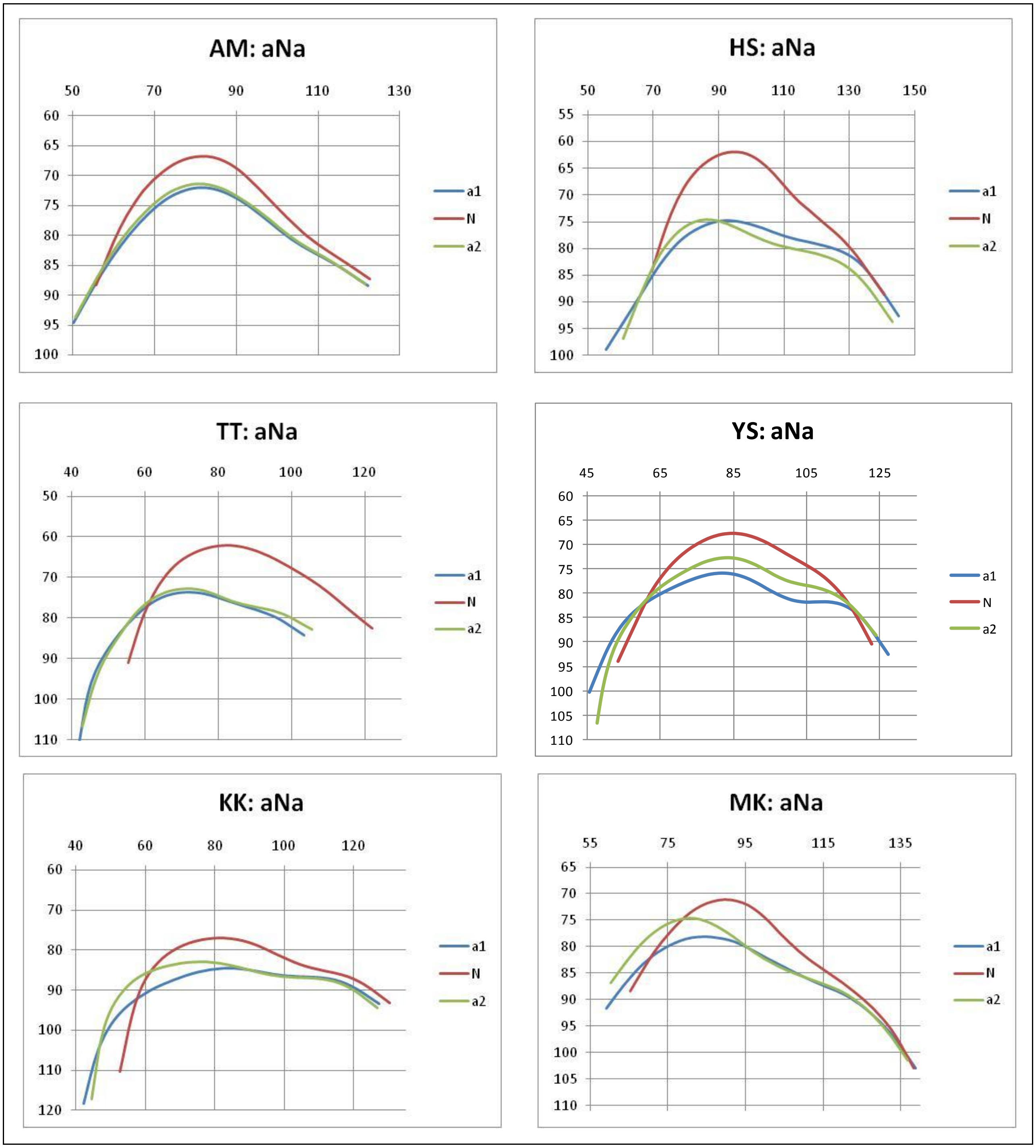

Figure 2.11. Average tracing: aNa

The tracings suggest that independent constriction degree should exist for the /N/ of all speakers. It follows that the place-specification hypothesis is supported in this environment.

Although the tongue body raising looks obvious, it is not clear whether this tongue activity is significantly different from each of the adjacent vowels. The next section shows the methodology used to confirm these points.

Below are SS-ANOVAs of the tongue contours of the 6 talkers producing /aNa/. Three graphs are presented: (i) /N/ vs. a1 in /aNa/, (ii) /N/ vs. a2 in /aNa/, and (iii) a1 vs. a2 in /aNa/; the main concern here is with the first two graphs. The general result is that /N/ has active dorsum raising for every speaker, which is observed from significantly different areas in (i) and (ii).

The following graphs are the one made in SS-ANOVA. Three graphs are made for each subject: (i) The upper left graph shows N of aNa vs. a1 of aNa, (ii) The upper right graph shows N of aNa vs. a2 of aNa, (iii) The lower left graph shows a1 of aNa and a2 of aNa. Red lines show tongue surface of /N/, and gray/black lines show tongue surface of [a].

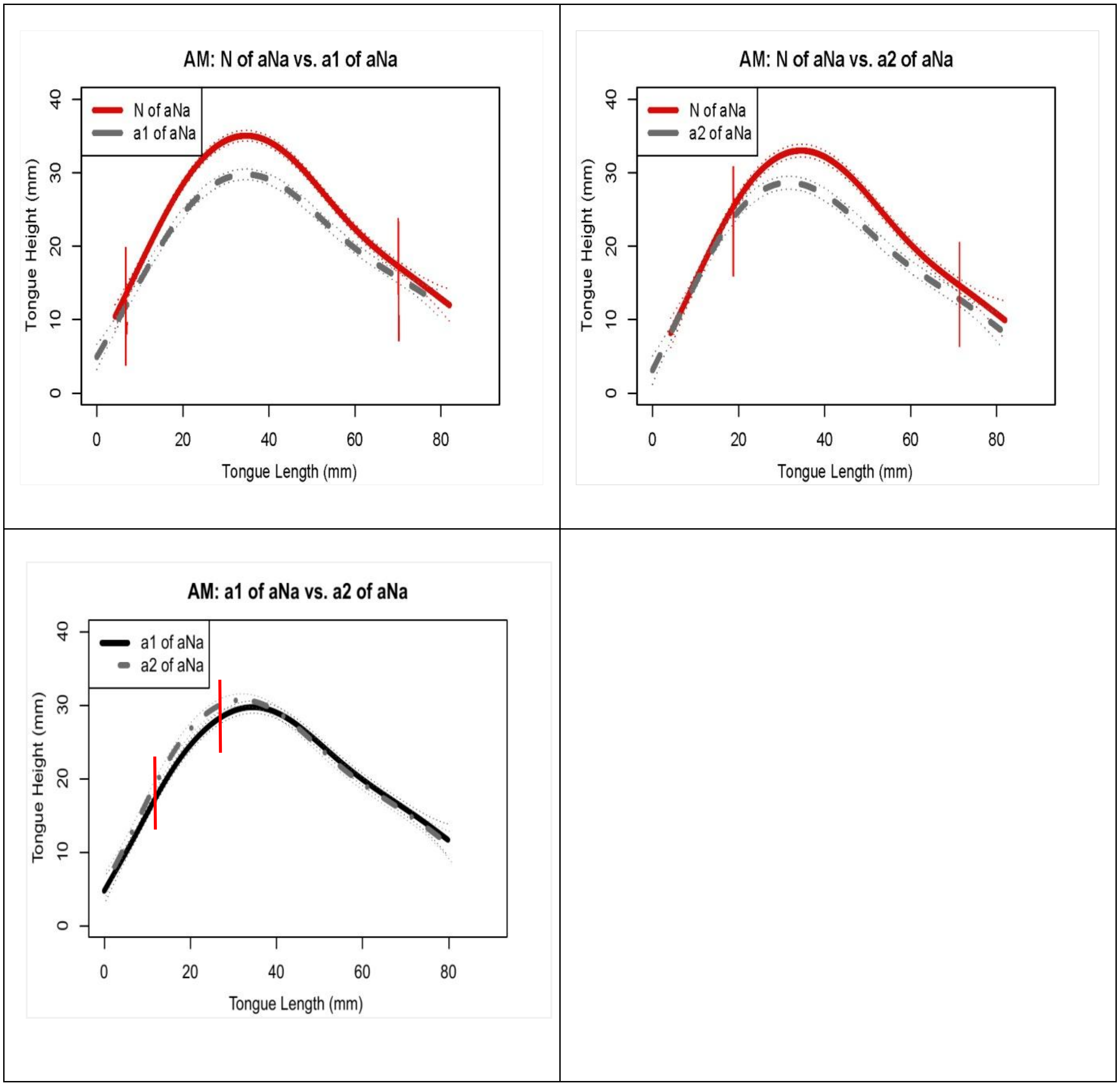

Figure 2.12. SS-ANOVA tongue-contour graphs: AM aNa

In speaker AM's production of /aNa/, shown in Figure 2.12, the dorsum is raised about 7 mm in the production of /N/. The peak of the tongue in /N/ is between 30-40 mm of the horizontal axis. The significantly different region is located around 8-70 mm (N vs. a1) and 20-72 mm (N vs. a2) out of approximately 80 mm tongue length, so presumably the region is postero-dorsum. Compared to a1, a2 is retracted/raised about 2 mm in the region around 13-28 mm of the horizontal axis .

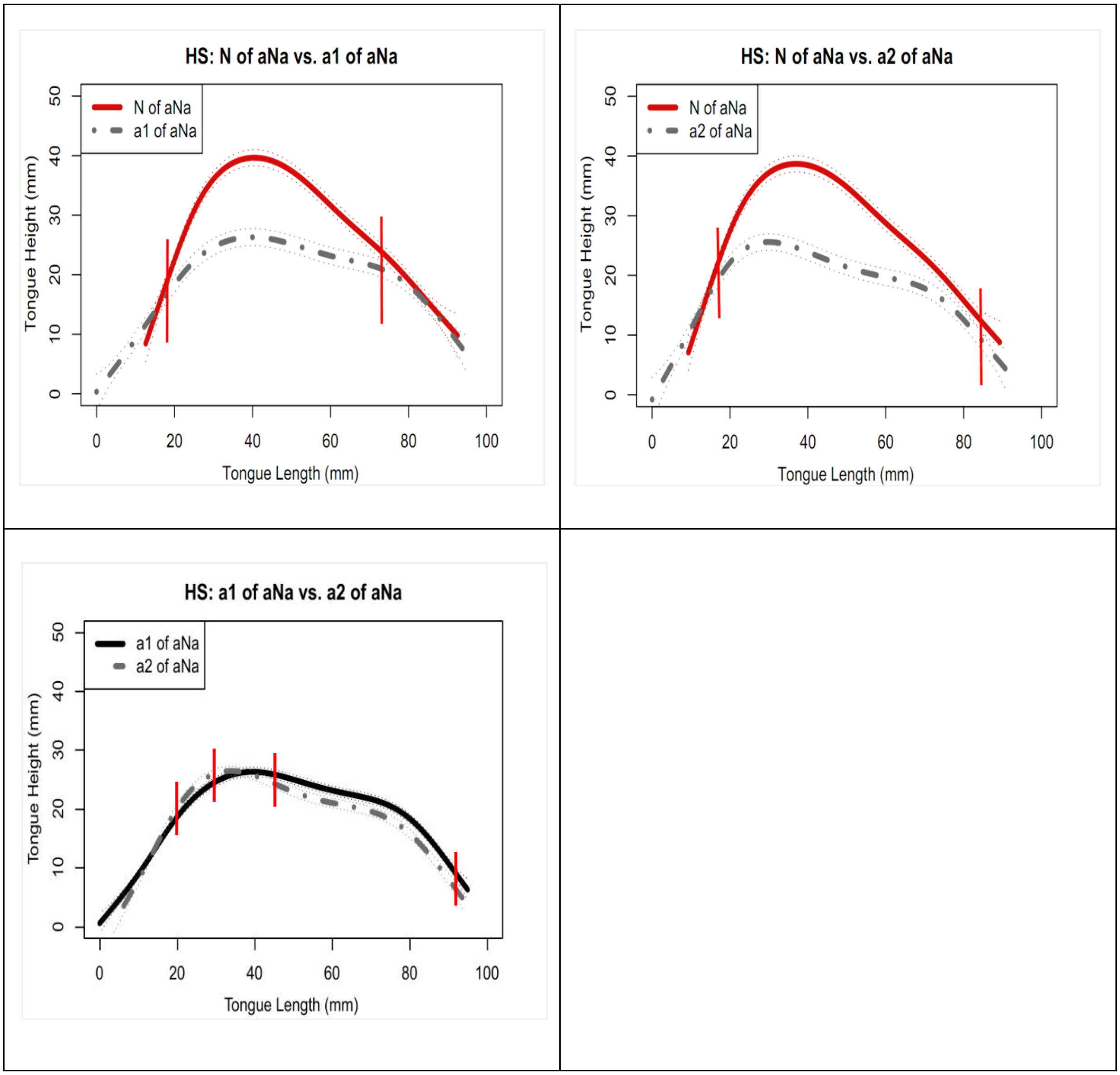

Figure 2.13. SS-ANOVA tongue-contour graphs: HS aNa

In speaker HS's production of /aNa/, shown above, the dorsum is raised about 15 mm in the production of /N/. The peak of the tongue in /N/ is between 30-50mm of the horizontal axis. The significantly different region is located around 20-70 mm (N vs. a1) and 20-85 mm (N vs. a2) out of approximately 95 mm tongue length, so presumably it is postero-dorsum. Compared to a1, a2 is lowered by about 2 mm in the region around 45-90 mm of the horizontal axis, and raised/retracted by 2 mm in the region around 20-30 mm of the horizontal axis.

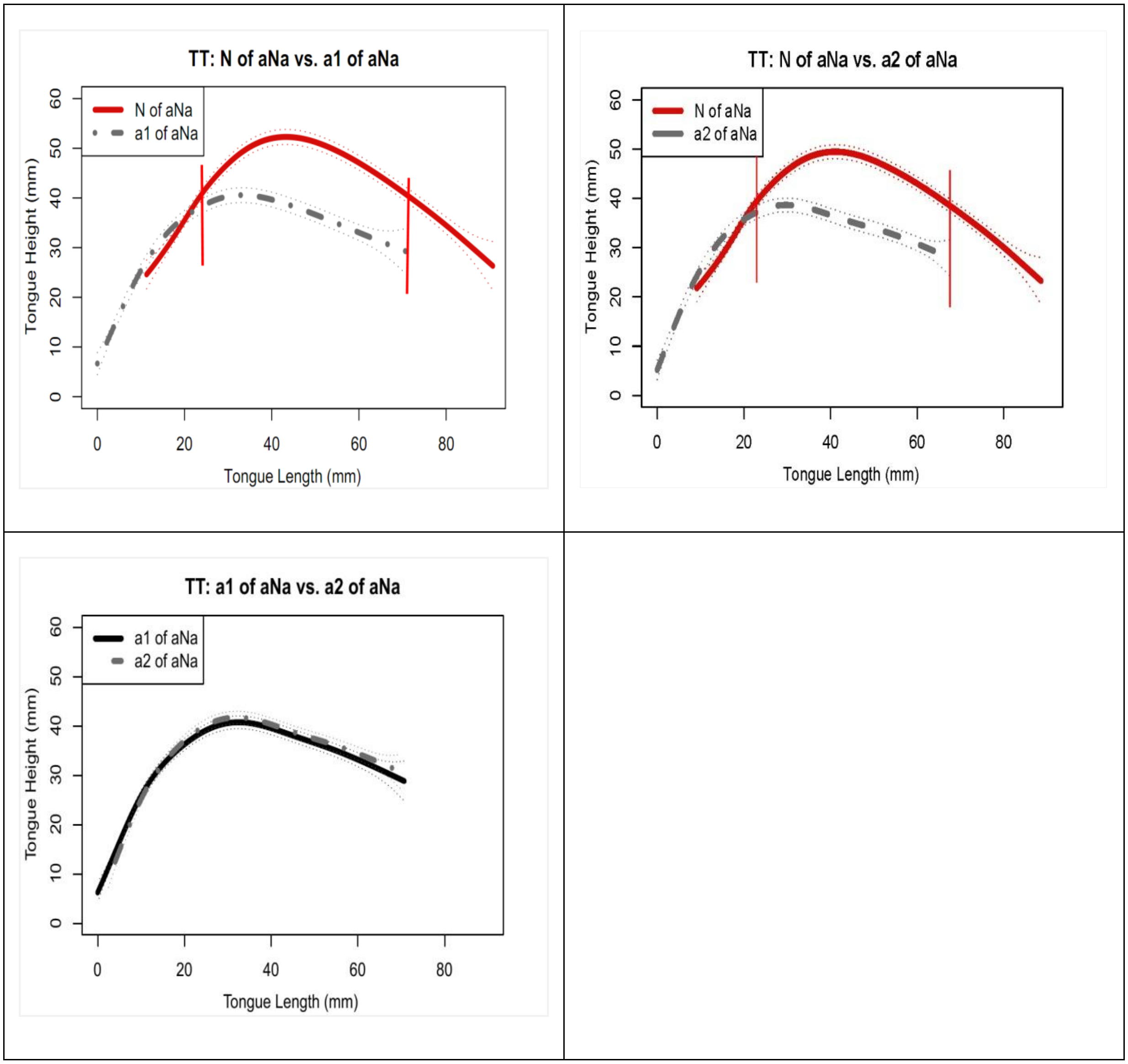

Figure 2.14. SS-ANOVA tongue-contour graphs: TT aNa

In speaker TT's production of /aNa/, shown above, the dorsum is raised about 10 mm in the production of /N/. The peak of the tongue in /N/ is around 40 mm of the horizontal axis. The significantly different region is located around 25-70 mm (N vs. a1) and 25-72 mm (N vs. a2) of the horizontal axis out of approximately 80 mm tongue length, so presumably it is postero-dorsum. There is no significant difference between a1 and a2.

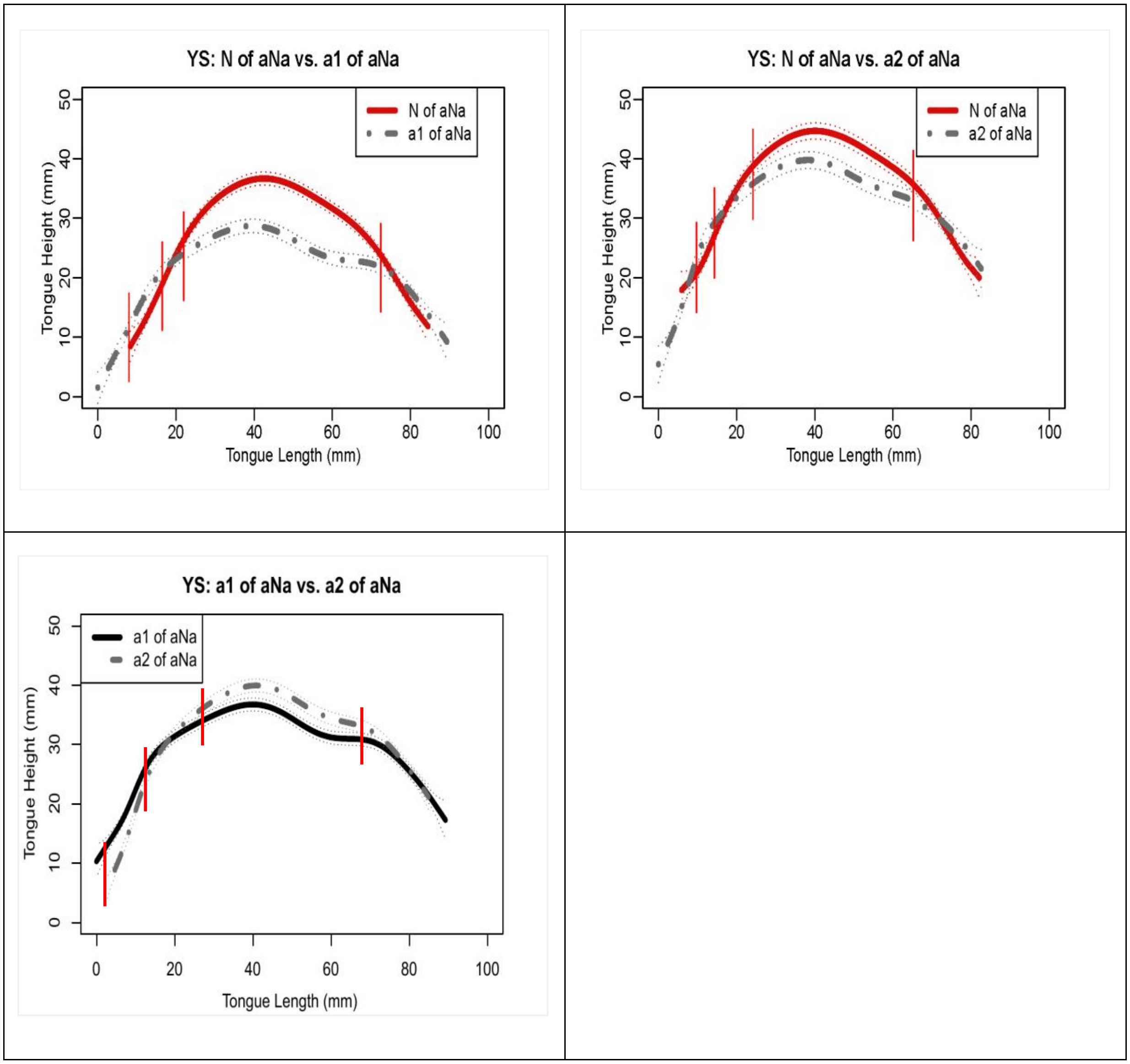

Figure 2.15. SS-ANOVA tongue-contour graphs: HS aNa

In speaker YS's production of /aNa/, shown above, the dorsum is raised about 10 mm in the production of /N/. The peak of the tongue in /N/ is around 40 mm of the horizontal axis. The significantly different region is located around 25-75 mm (N vs. a1) and 25-65 mm (N vs. a2) of the horizontal axis out of approximately 90 mm tongue length, so presumably it is postero-dorsum. Compared to a1, a2 is higher by 3-5 mm at the region around 28-67 mm of the horizontal axis, and is further forward by 2-5 mm at the region around 2-17 mm of the horizontal axis.

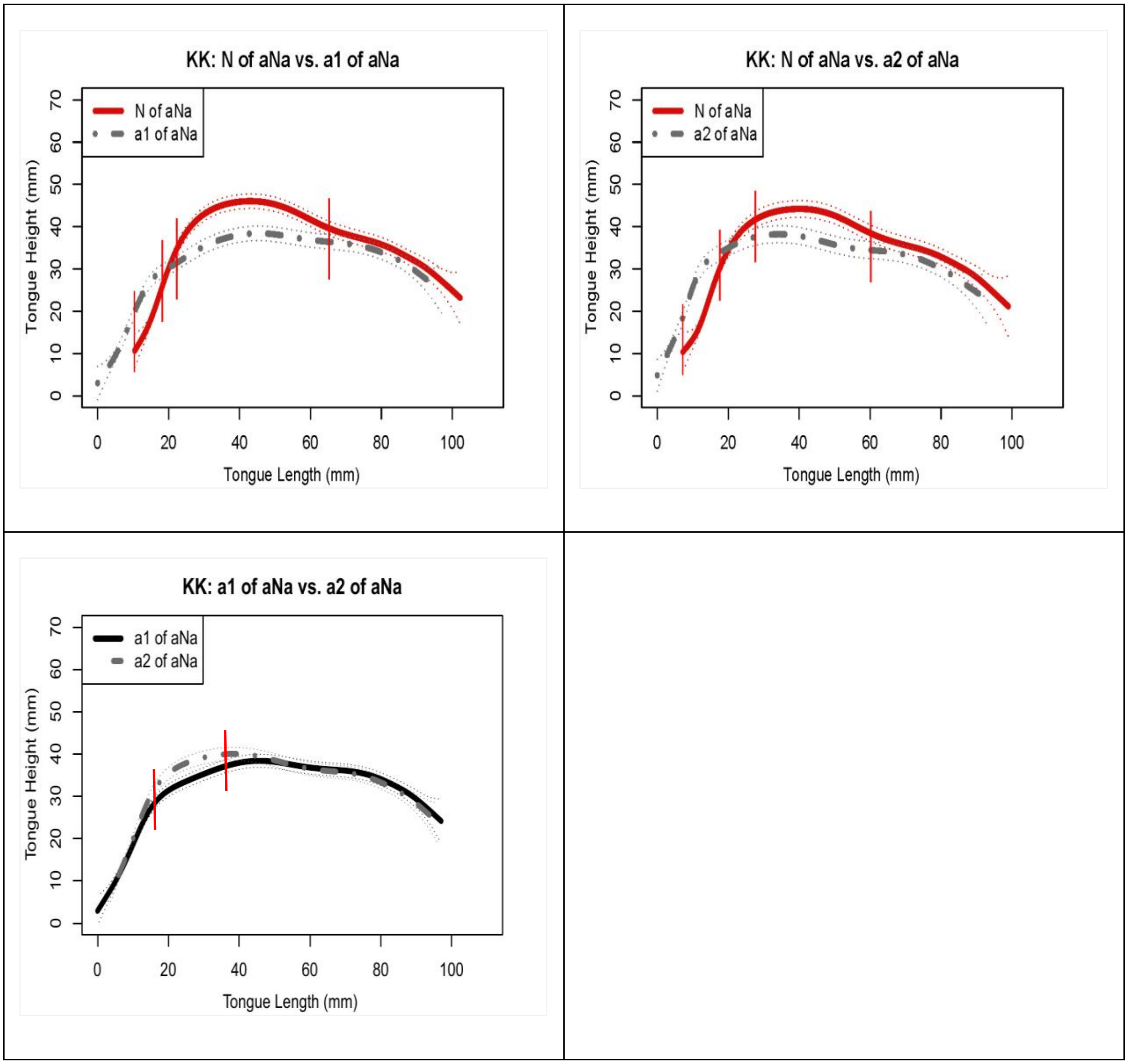

Figure 2.16. SS-ANOVA tongue-contour graphs: KK aNa

In speaker KK's production of /aNa/, shown above, the dorsum is raised about 10 mm in the production of /N/. The peak of the tongue in /N/ is between 30-50 mm of the horizontal axis. The significantly different region is located around 25-65 mm (N vs. a1) and 30-60 mm (N vs. a2) of the horizontal axis out of approximately 100 mm tongue length, so presumably it is postero-dorsum. Compared to a1, a2 is retracted/higher by 2-5 mm at the region around 18-38 mm of the horizontal axis.

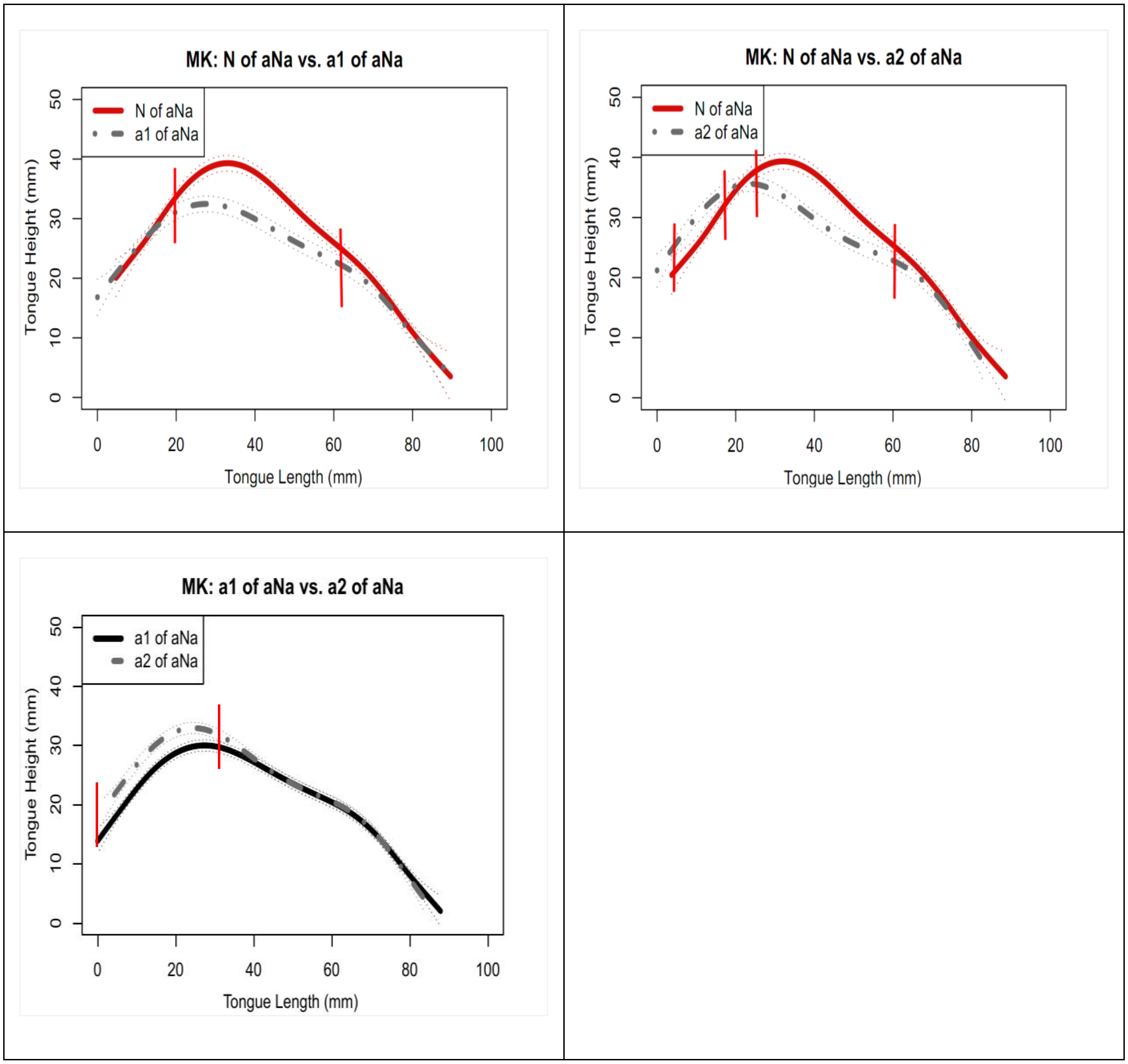

Figure 2.17. SS-ANOVA tongue-contour graphs: MK aNa

In speaker MK's production of /aNa/, shown above, the dorsum is raised about 10 mm in the production of /N/. The peak of the tongue in /N/ is between 30-40 mm of the horizontal axis. The significantly different region is located around 20-60 mm (N vs. a1) and 23-60 mm (N vs. a2) of the horizontal axis out of approximately 90 mm tongue length, so presumably it is postero-dorsum. Compared to a1, a2 is raised/retracted by about 5 mm at 0-30 mm of the horizontal axis.

As can be seen in all the (i) and (ii) graphs, all subjects show a significant tongue dorsum raising by approximately 7 mm to 15 mm in the production of /N/, in the postero-dorsal region. This suggests that /N/ has an independent place feature.

Overall, all speakers' a1 vs. /N/ and /N/ vs. a2 have some region where the dotted lines which indicate 95% confidence interval do *not* overlap (Davidson 2006b).[37] The focus of this section is whether *both* a1 vs. /N/ and /N/ vs. a2 are significantly different. All the speakers except TT also show significant difference between a1 vs. a2, but this is not our concern. The results show that for every speaker, /N/ diverges from both a1 and a2, suggesting that /N/ has an independent place.

2.4. Discussion

Significant tongue raising is attested for all 6 speakers' /N/s. Compared to the adjacent /a/, the raising ranges from 7 mm to 15 mm. From the graphs, it is clear that /N/ has an independent CD for all speakers. At this point, however, it is not clear whether /N/ has an independent CL because the tongue contour graphs are intended to present where a significant difference exists in the overall tongue between the two tongue contours, rather than finding where the CL of a segment is relative to the surrounding structures of the vocal tract (this point will be taken up in chapter 4). In this chapter it is confirmed that Japanese /N/ is not a case of complete placelessness (see sec. 1.4.). Thus, the hypothesis that Japanese /N/ is not placeless is partially supported. This result is consistent with the intuition of native speakers of Japanese that some dorsal constriction is happening during the production of /N/.

Placelessness for /N/ has been traditionally assumed in the literature, based on i) the phonological evidence of placeless /N/ (as in sec. 1.2.1) and ii) the logic of the assumption that there is no mismatch between phonology and phonetics (as in sec. 1.1.4.). But if the experimental

[37] Thus, for example, N vs. a2 for HS has approximately a 60 mm non-overlap region (x-axis), while a1 vs. a2 for KK has only about a 20 mm non-overlap region, but those pairs are treated as equally different (>.05). Likewise, however big or small the non-overlap height (y-axis) would be, the pairs are treated as equally different (>.05); for example, the non-overlap height is less than 5 mm in a1 vs. a2 for KK, but more than 10 mm for a1 vs. N for TT, but those pairs are treated as equally different. One may cast doubt on the pairs that show only a tiny portion of difference in the x-axis and/or y-axis, but note that those potentially doubtful pairs are limited to pairs of a1 vs. a2, which is not our primary concern.

results suggest /N/ has a place, then both phonetically and phonologically it should not be placeless.

The results from the new data presented here shed light on the phonetics-phonology interface. Visual types of articulatory data of Japanese /N/ – photographs from x-rays (Naito 1961, Uemura & Takada 1990) or ultrasound (Nakajima 2003) – do exist in previous literature, but the data was limited to one speaker and/or lacked quantitative measurements. Thus it was not known whether the same type of constriction occurs for every speaker, and whether the constriction is discrete enough to make the place of /N/ independent. The current study shows that dorsal constriction is happening for all six speakers, and SS-ANOVA shows that it is statistically significant.

What was not expected from my prediction is the difference between a1 and a2. These phonologically identical vowels are shown to be significantly different for everyone except TT. Speakers having this difference consistently show that a2 is more raised, or more similar to /N/ in the tongue posture. This could be caused by the tone differences between High (a1) and Low (a2), which could affect larynx height (Erickson, Baer and Harris 1983, Meechan 1992), or a language-specific C-to-V carryover effect (Kondo 2006). Further exploration of the cause of this difference is outside the scope of my research.

2.5. Conclusion

The study in this chapter tested the hypothesis that Japanese /N/ has a place specification, reporting an ultrasound experiment on six native speakers of Tokyo Japanese. The results of SS-ANOVAs indicate a discrete oral constriction around the postero-dorsal region of the tongue in the production of /N/. This supports the hypothesis that the place value of /N/ is not complete placelessness, because the dorsum raising, ranging from 7 mm to 15 mm compared to the flanking /a/, occurs across speakers. This multiple case study concludes that /N/ has a distinct place target for all speakers. The CL of /N/ is is a separate issue, which will be taken up in chapter 4.

Under the assumption of the bidirectional mapping between the abstract/symbolic level and the concrete/physical level (see sec. 1.1.4.), only two patterns of relations should be allowed between the output of phonology and the output of phonetics: (i) A specified feature in phonology is realized with discrete patterns in phonetics, and (ii) An unspecified feature in phonology is realized with interpolation patterns in phonetics. If Japanese /N/ is unspecified for place, then an interpolation between a1 and a2 is expected, but the experimental evidence found otherwise.

The current result that /N/ has greater constriction than the identical adjacent vowels further poses a question about what segment category the intervocalic /N/ should belong to. Browman and Goldstein (1992: 30) state “The consonantal gestures typically have a greater degree of constriction and a shorter time constant (higher stiffness) than the vocalic gestures.” Thus, /N/ is more likely to be a kind of consonant than a vowel. Furthermore, Padgett (2008) argues that constriction degree distinguishes glides from vowels, thus this /N/ may be best categorized as a glide. Therefore, the previous description of /N/ as a nasalized low vowel [ã] (cf. Yatabe 1987) turns out to be unsupported in any intervocalic context.

The remaining questions include whether /N/ must have a consonantal place, and where that place is. These questions will be explored in Chapter 4.

Chapter 3 **The Japanese Glottal Fricative**

3.1. Introduction

This chapter tests the hypothesis that that the glottal fricative in Japanese has a specified place. Multiple case studies of Tokyo Japanese are conducted, in order to examine phonetic and phonological variations across speakers. Overall, the experimental results support the hypothesis, although there is some inter-speaker variation.

3.1.1. Placeless vs. Pharyngeal

Crosslinguistic evidence has shown that glottal fricatives often behave as if they were phonologically *placeless*, being transparent to harmony (Steriade 1987a), and are phonetically underspecified, showing an interpolative quality between adjacent vowels (Keating 1988). Phonological acquisition data also suggests that glottal fricatives in English are underspecified and lack a place node (Stemberger 1993).

However, the phonetic status of glottal fricatives is not crosslinguistically uniform. McCarthy (1991, 1994) has shown that Arabic glottals are *pharyngeal*, rather than purely laryngeal (which is interpreted as being placeless). These findings are based on not only the properties of the glottal fricatives themselves, such as pharyngeal constrictions visible in X-ray images, but also the effect they have on adjacent segments, such as vowel lowering and cooccurrence restrictions. Similar evidence is also found in typologically different languages (see Shahin & Blake 2004, Namdaran 2006 for pharyngeal consonants causing a vowel lowering effect in Salish). However, in this thesis, I will test the glottal fricative itself, rather than its effect on adjacent segments. Furthermore, there are cases in which pharyngeal and placeless glottals *coexist* within a language (see Shaw 1991 for Nisgha [Tsimshianic], and Meechan 1992: 103 for Khmer [Austro-Asiatic]).

Previous literature has argued that the laryngeals /ʔ, h/ could be i) pharyngeal, ii) placeless, or iii) both pharyngeal and placeless. It is not known whether their specification must be stipulated from language to language, or is predictable from other aspects of the language. There has been controversy over whether the specification of /h/ is predictable from the segment inventory of the language: i.e., whether or not the pharyngeal specification of laryngeals is a consequence of a rich guttural inventory (see McCarthy 1991, Lloret 1995, Rose 1996, Bessell

1992 and Bessell & Czaykowska-Higgins 1992). In this context, languages with a rich guttural inventory have been often brought up, but languages without them have been largely left out of the discussion.

Japanese, which has only /h/, /N/ and /k, ɡ/ in the post-palatal area, has not been discussed much in this context. But the majority of researchers believe that Japanese /h/ is placeless. There are at least two reasons to believe so. First, in Japanese phonology, there is an established allophonic rule which turns /h/ into a palatal fricative before /i/, and to a bilabial fricative before /u/. In this rule, /h/ is the undergoer of the assimilation. If being the undergoer (or non-blocker) of assimilation can be a diagnostic for placelessness (e.g., Paradis & Prunet 1991, but see also de Lacy 2006 for criticism), /h/ can be viewed as placeless. Second, the oral posture of /h/ can be labelled as that of a voiceless vowel, since the oral posture is the same as that of the following vowel, /a, i, u, e, o/, which is supported by X-ray tracings (Uemura & Takada 1990).

The question unanswered in this placeless /h/ assumption is why the allophonic rules apply to /h/ before high vowels only, rather than before all vowels. In my view, if Japanese /h/ is assumed to have a pharyngeal place of articulation, the assimilation of /h/ in these high vowel environments would be explained in terms of articulatory conflict at the tongue root (Meechan 1992, Archangeli & Pulleyblank 1994, Gick & Wilson 2006). Gick & Wilson argue that conflicting tongue root targets beget crosslinguistically diverse repair strategies. Furthermore, in many languages that have a pharyngeal /h/, a sequence of /h/ and a high vowel (*hi, *hu) is banned. In languages with sequences of this kind, vowel lowering or laxing may occur (e.g., /hilt/ > [helt] 'many' in Gitksan (Rigsby 1986: 205; see Shahin & Blake 2004 for a vowel lowering effect in Salish, and Shaw 1991 for both pharyngeal and placeless glottals within Nisgha).

The current study uses ultrasound to examine the phonetic implementation of /h/ when it is adjacent to /a/. I will test the hypothesis that the glottal fricative in Japanese has a specified place.

3.1.2. Prediction

The predictions of generative phonetics can be in both directions between phonetics and phonology: particular types of *phonological* patterning predict a particular *phonetic* implementation and particular *phonetic* patterns predict the presence or absence of a feature *phonologically*. Because the predictions are bidirectional, based on the phonetic evidence we should be able to detect whether the feature is specified or not phonologically. In this section I will clarify the type of phonetic evidence that would indicate a particular phonological interpretation, and vice versa. Simply speaking, if /h/ in /ahha/ has an interpolative quality in the trajectory from a1 (the first [a]) to a2 (the second [a]), it is placeless; however, if it has a distinct target different from both a1 and a2, a place has to be specified on /h/.

The question is, with the use of ultrasound data, what must be shown to argue for an interpolative quality, and what must be shown to argue for an independent place feature. This point is illustrated below.

The representational structure in (3.1) illustrates the case where the place feature of /h/ is unspecified in the phonology.

(3.1) Placeless /h/ in the output of phonology:

```
  a       h       a
  |               |
 V-pl           V-pl
  |               |
  α               α
```

The figures below show the corresponding phonetic implementation. Since I will test placelessness by examining the physical movement of the tongue, the predicted phonetic implementation is illustrated by way of schematic representations of midsagittal tongue tracings. In the figures in this section, the red solid line denotes /h/, the broken blue line denotes a1, and the dotted green line denotes a2.

The essence of the placeless /h/ is its interpolative nature. When /h/ lacks a featural value for place, its physical signal should simply be somewhere on the trajectory between V1 and V2. Phonologically speaking, a1 and a2 are identical, but due to differences such as pitch height and syllable position, their realizations may not be exactly the same. So in addition to the case of Figure 3.1 in which V1 and V2 are the same, the case of Figure 3.2, in which V1 and V2 have significant differences, should also be considered.

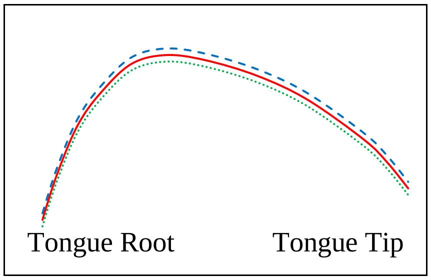

Figure 3.1. Predicted placeless /h/ in the output of phonetics: when V1=V2

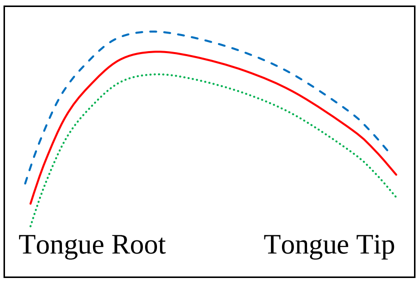

Figure 3.2. Predicted placeless /h/ in the output of phonetics: when V1$\neq$V2

Since interpolation appears when the segment lacks a featural value for place, the value for the feature should simply be the appropriate value based on the trajectory between V1 and V2. Thus, all else being equal, during the temporal span of the segment, being closer to V1 would result in a value more like V1's, and being closer to V2 would result in a value more like V2's. [38] When the flanking vowels are identical, as in Figure 3.1, /h/ should overlap with the flanking vowels as well. In this case, statistically, no pair of segments should show any significant difference. But when the flanking vowels are not identical, as in Figure 3.2, /h/ should be between V1 and V2. Statistically, each of a1 vs. /h/, /h/ vs. a2, and a1 vs. a2 should show a significant difference. It does not matter whether the non-overlapping parts are the overall large area from tongue root to tongue tip, or a small area of it. Figure 3.1 and Figure 3.2 above show the examples where the non-overlapping area is the overall area.

The representational structure in (3.2) below illustrates the case where the place feature of /h/ is specified in the phonology.

[38] It would be interesting to see how the tongue contour linearly shifts temporally from the onset of /h/ to the offset, but the midpoint of /h/ should be enough to test whether /h/ is placeless or not.

(3.2) Pharyngeal /h/ in the output of phonology:

a	h	a
|	|	|
V-pl	C-pl	V-pl
|	|	|
α	β	α

The figures below show the corresponding phonetic implementation. If /h/ has an independent place feature, the contour of /h/ should be significantly different from both V1 and V2, and at least a part of the tongue should be outside both V1 and V2. Figure 3.3 shows the case where the flanking vowels are identical (thus not significantly different), and Figure 3.4 shows the case where they are not identical (thus significantly different).

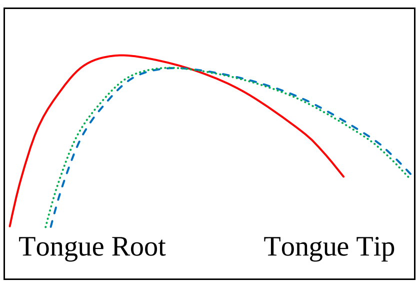

Figure 3.3. Predicted pharyngeal /h/ in the output of phonetics: when V1=V2

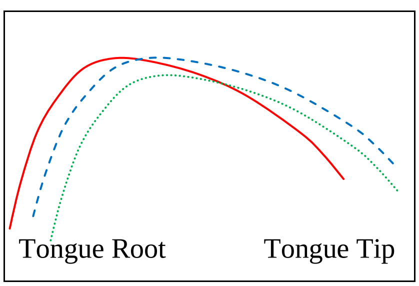

Figure 3.4. Predicted pharyngeal /h/ in the output of phonetics: when V1 ≠ V2

/h/ retracts the tongue root and/or dorsum compared to the adjacent vowels. This point would not be affected, whether V1 and V2 are the same or different. A digression from both V1 and V2 is an important diagnostic for having a constriction gesture (which thus has some constriction-location target, i.e., a “place”). Statistically speaking, both a1 vs. /h/ and /h/ vs. a2 should include significantly different parts. If only one pair of them shows a significant difference, then it could be interpreted as assimilation (see section 4.3.1. for a discussion on assimilation-type). The current experiment focuses on whether or not there is an independent CL in the articulation of /h/. The remaining sections are organized as follows: Section 3.2. lays out the methodology, section 3.3 shows the results, section 3.4. summarizes the results and discusses the implications, and section 3.5. concludes the chapter.

3.2. Methodology

3.2.1. Subjects

The subjects are the same as in chapter 2.

3.2.2. Stimuli

3.2.2.1. Selection

All stimuli consist of pseudo words. Real words were not used because the phonetic/phonological environments of the existing words are too diverse to be controlled to meet the criteria of the experimental purpose. All the words were made as uniform as possible, so that the potential influence of diverse phonetic, phonological, and morphological factors could be avoided. The stimuli relevant for the experiment involving /h/ are given below.

(3.3) Stimuli in /h/ series

a. Target word: ahha

b. Dummy words: ihhi, ihha, ahhi, ahhe, ihhe, uhhe, ahho, ihho, uhho

The target word was set as having /a/ on both sides of the /h/. This is because /a/ is the only low vowel in Japanese, making the tongue floor go all the way down, so that it will make any consonantal constriction stand out.[39] One may think that if /h/ is pharyngeal, and if /a/ is also pharyngeal, then the consonantal constriction for /h/ would probably stand out the most obviously in /ihhi/. It may be true for the /h/ of other languages in general, but Japanese /h/

[39] However, Articulatory Phonology predicts /a/ might make the place of /h/ similar to an articulatory setting. See also fn4.

allophonically becomes a palatal fricative before /i/, and a palatal fricative is unarguably not placeless.[40] On the other hand, it is not known how Japanese /h/ is articulated before /a/. Even if /h/ and /a/ are both pharyngeal, the major difference should be [voice] and [spread glottis], which should be independent of lingual movement. Thus if something is found in the lingual movement of /h/ in the context of /a/, then this would be a piece of evidence that some feature/gesture is required for /h/. The current methodology using ultrasound effectively catches such a type of sound, which is audibly and introspectively unclear. Nine dummy words were created, and randomized with the target word.

As for the segment structure of /h/ in the stimuli, geminates were selected instead of singletons. There are several merits in doing so. First, in general, the farther apart the targeted segments are, the more slowly interpolation can be observed. Pierrehumbert and Beckman (1988) illustrate this point: the way tone interpolation is in Japanese is different depending on how far from the initial syllable the H tone is located, which is usually realized as an L tone. Pitch rises slower when the tone is farther from L. In the same way, geminates should give us more time to see the transition between the adjacent vowels. [41] Second, /áhha/ instead of /aha/ is used in Uemura & Takada's (1990) x-ray tracings of the vocal tract, where the slow movement of geminate /h/ also seems visible. Interestingly, the overlay of a1, h1 (the first half of /hh/) and h2 (the second half of /hh/) reveals that the dorsum peak of h2 looks higher and more retracted than that of h1 (ibid p.328). This suggests that the transition from the beginning of /h/ to the end of /h/ would be more easily detectable when C is stretched in the temporal span.[42]

In addition to the geminate condition above, the following criteria were set. i) *Nouns of loanwords*: It is known that the Japanese lexicon consists of native words, Sino-Japanese words

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[40] The next best option may be /ehhe/, but this option would not enable us to compare /h/ with N, which was already analyzed.

[41] The multiple measurements would present how the articulatory transition looks during the time span, or whether the shape of the transition is a plateau (categorical) or a cline (gradient) (cf. Cohn 1990, 1993). However, I did not use that method, because a token where the flanking vowels are identical is not appropriate to see the gradual difference in time. Tokens such as /ihha/, where the opposite values of a feature are available, would be more suitable for that method.

[42] Kochetov's (2012) electropalatographic study reports there are articulatory differences between geminate and singleton obstruents in Japanese in terms of linguopalatal contact. The finding is consistent with informal observation made in Sakuma (1929). The difference between geminates and singletons is also observed crosslinguistically: See Payne (2006) for Italian, Son, Kim & Cho (2012) for Korean labial stops, Heselwood & Al-Tamimi (2011) for laryngeal and pharyngeal consonants in Jordanian Arabic. Thus, future studies should include both /hh/ and /h/, and a comparison with unambiguously non-lingual articulations (e.g., apa vs. appa).

and loanwords, and some phonotactic constraints are different depending on the lexical stratum and/or grammatical category (Itô & Mester 1995a, b, 1999, 2003, Itô, Mester & Padgett 1995, 1999). The sequence /hh/ only occurs in nouns of loanwords and onomatopoetic expressions in the native words. ii) *Disyllabicity*: As the interest here is how [hh] is phonetically implemented relative to the flanking vowels /VhhV/, any additional segments will not be necessary. Words were created to be as compact as possible. iii) *Initial-accented* pattern: The most dominant accent pattern for trimoraic loanwords in Japanese is initial-accented (Kubozono 2006). This was discussed in section 2.2.2.1.

3.2.2.2. Instructions

Instructions were the same as in section 2.2.2.1.

3.2.3. Procedures

Data-gathering procedures followed those described in section 2.2.3.

3.2.4. Analysis

Most analyses are the same as in sec. 2.2.4. except for the following.

Two different analyses are shown: I used SS-ANOVA to find the area of significant difference of the tongue contours between /h/ vs. a1, /h/ vs. a2, and a1 vs. a2. In addition, I used boxplots to compare the tongue peaks of a1, /h/ and a2.[43] The data of the tongue peaks is split into a y-value (CD) and an x-value (CL), and each value is compared separately.

The statistical analyses were done by t-test (unpaired),[44] using the Holm-Bonferroni method (Holm 1979, Abdi 2010). This method is used in order to reduce the error rate arising from comparisons of several hypotheses in the same test. Throughout this dissertation, three pairs of null hypotheses (e.g., a1 vs. /h/, /h/ vs. a2, and a1 vs. a2) are tested. For example, Table 3.2 presents the results of all pairs in the test for all speakers. Under the normal method, the P-value designating a significant difference is $<.05$ across the pairs consistently, regardless of the

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[43] The tongue peak appears as the lowest value in the y-axis. In Excel spreadsheets exported from .con files, I searched the lowest value of y-axis and recorded it with the corresponding x-value. The boxplot analysis was done for /hh/, where it is not clear whether the constriction event is happening vertically or horizontally. The boxplot analysis was not necessary for /N/ in chapter 2, because the vertical raising is obvious in SS-ANOVA.

[44] I used an online t-test: http://www.physics.csbsju.edu/stats/t-test_bulk_form.html

number of hypotheses. In contrast, under the Holm-Bonferroni method, the P-value designating a significant difference is adjusted based on the number of hypotheses, and is variable across the pairs in the same test. For a test having three hypotheses, for example, three kinds of P-values, i.e., $<.0166$ (0.05/3), $<.025$ (0.05/2), $<.05$ (0.05/1) are attained. Then the actual smallest P-value must be $<.0166$, the second smallest one must be $<.025$, and the third smallest one must be $<.05$. Everywhere (after Figure 3.11.), the p-values are shaded in green if they are below the significance levels (for alpha = .05) that have been adjusted by the Holm-Bonferroni method, and shaded in gray if they are above the adjusted levels but below an unadjusted significance level of .05. Thus, YS's a1 vs. h (.034) and a1 vs. a2 (.041) are greater than .0166, and .025 respectively;[45] therefore, neither is significantly different under the Holm-Bonferroni method.

3.3. Results

3.3.1. SS-ANOVA

Figure 3.5 to Figure 3.10 are SS-ANOVA tongue-contour graphs for individual speakers (the tongue tip is at the right). A pair of vertical red lines indicate the area of significant difference between two lines (see section 2.2.4. for how these lines were drawn).

[45] However, as soon as we encounter a p-value that is above the adjusted level, we are supposed to stop and reject the comparisons with higher p-levels also, even if they happen to fall below their adjusted level. Thanks to Gunnar Hansson for assisting me to understand this.

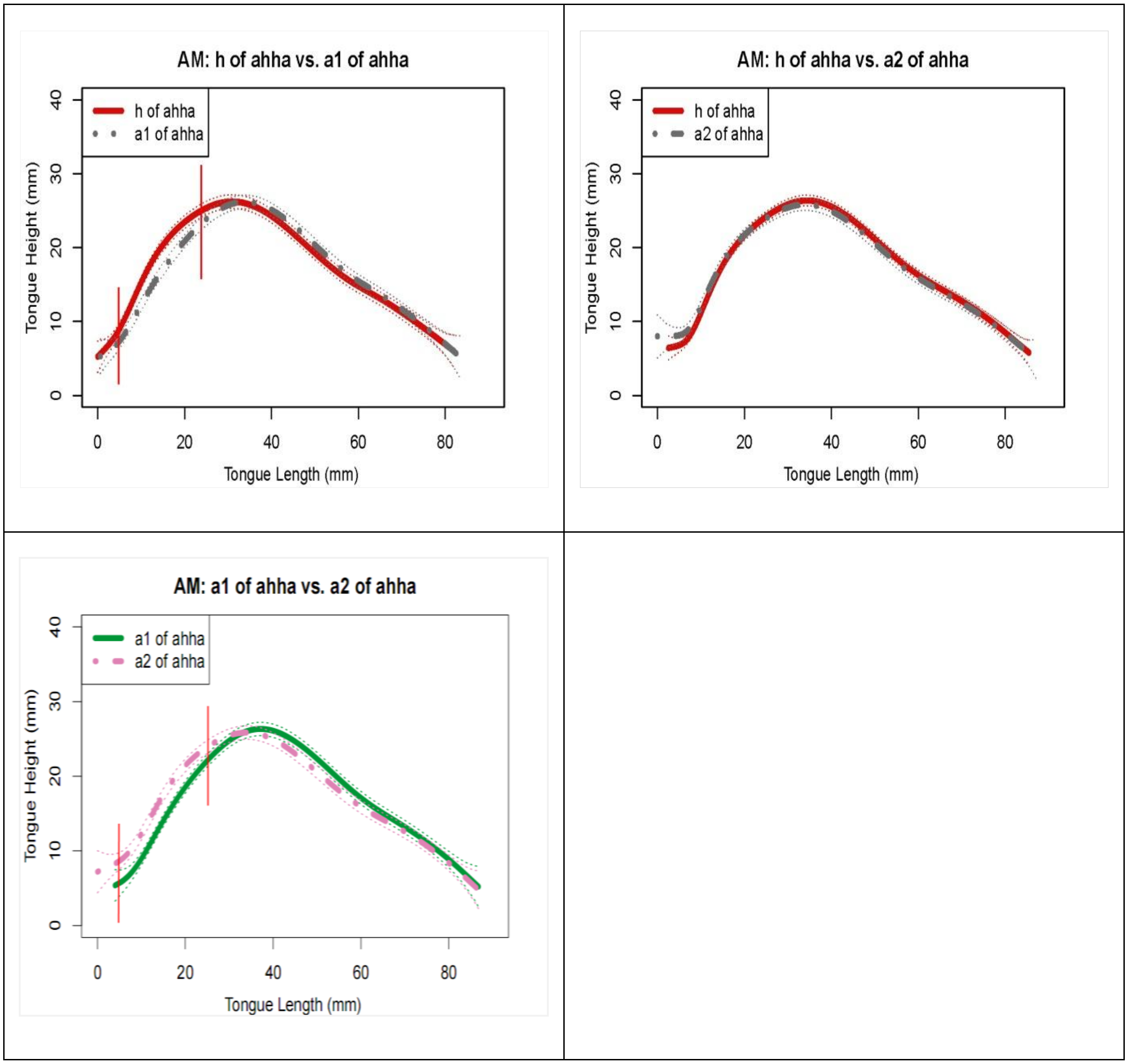


Figure 3.5. SS-ANOVA tongue-contour graphs: AM ahha

In speaker AM's production of /ahha/, shown above, /h/ is significantly different from a1, though it is the same as a2. As the pair of vertical red lines show, the constriction of /h/ is found at the posterior dorsum, and is retracted towards the pharyngeal wall. a2 is retracted compared to a1.

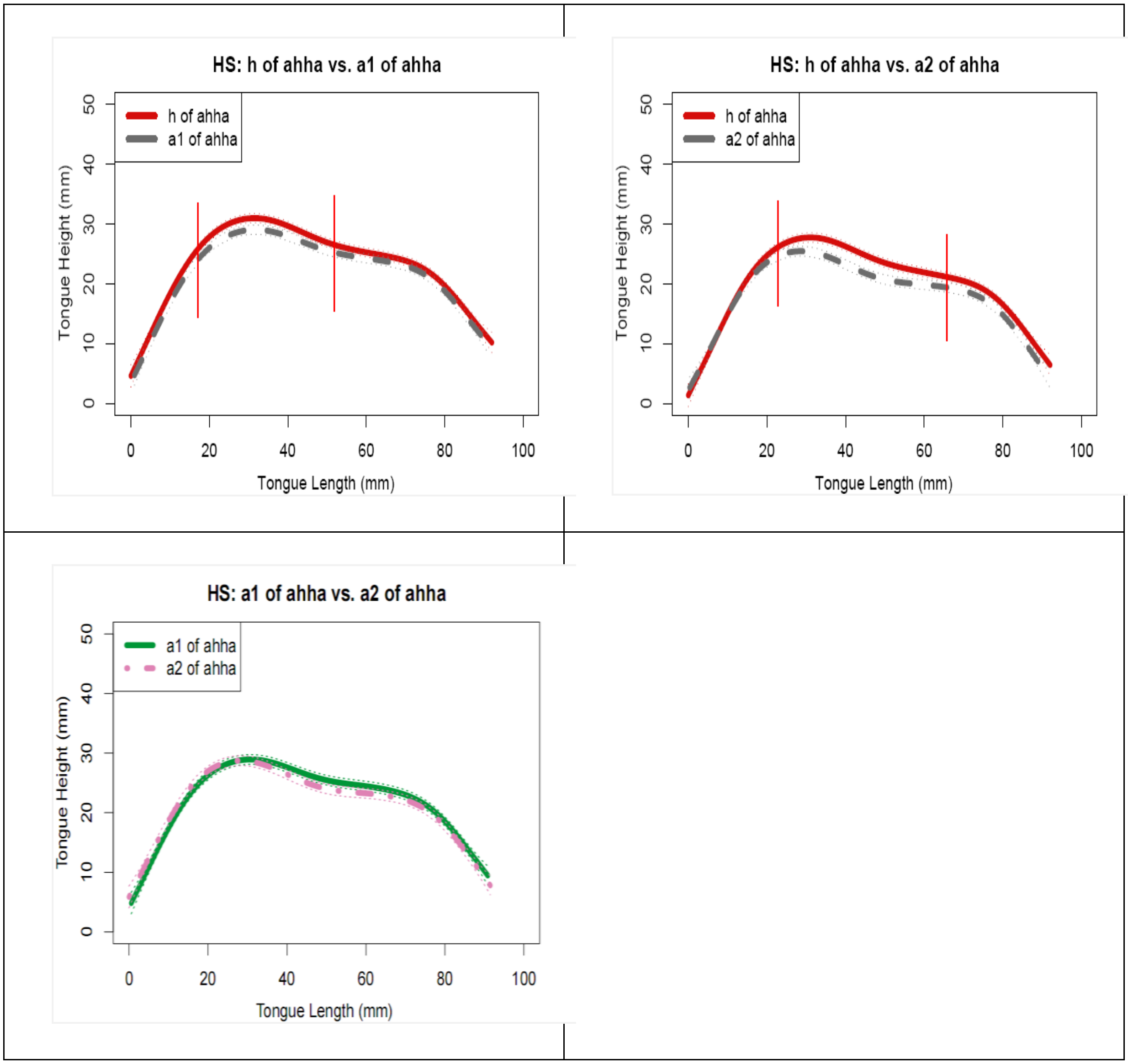


Figure 3.6. SS-ANOVA tongue-contour graphs: HS ahha

In speaker HS's production of /ahha/, shown above, /h/ is different from both a1 and a2. The area showing a significant difference is larger in h vs. a2 than in h vs. a1. This is probably because in the production of a2, the center of the tongue is lowered compared to a1, though it is not significant. The constriction of /h/ is found at the posterior dorsum and the anterior dorsum, where upward movement is found.

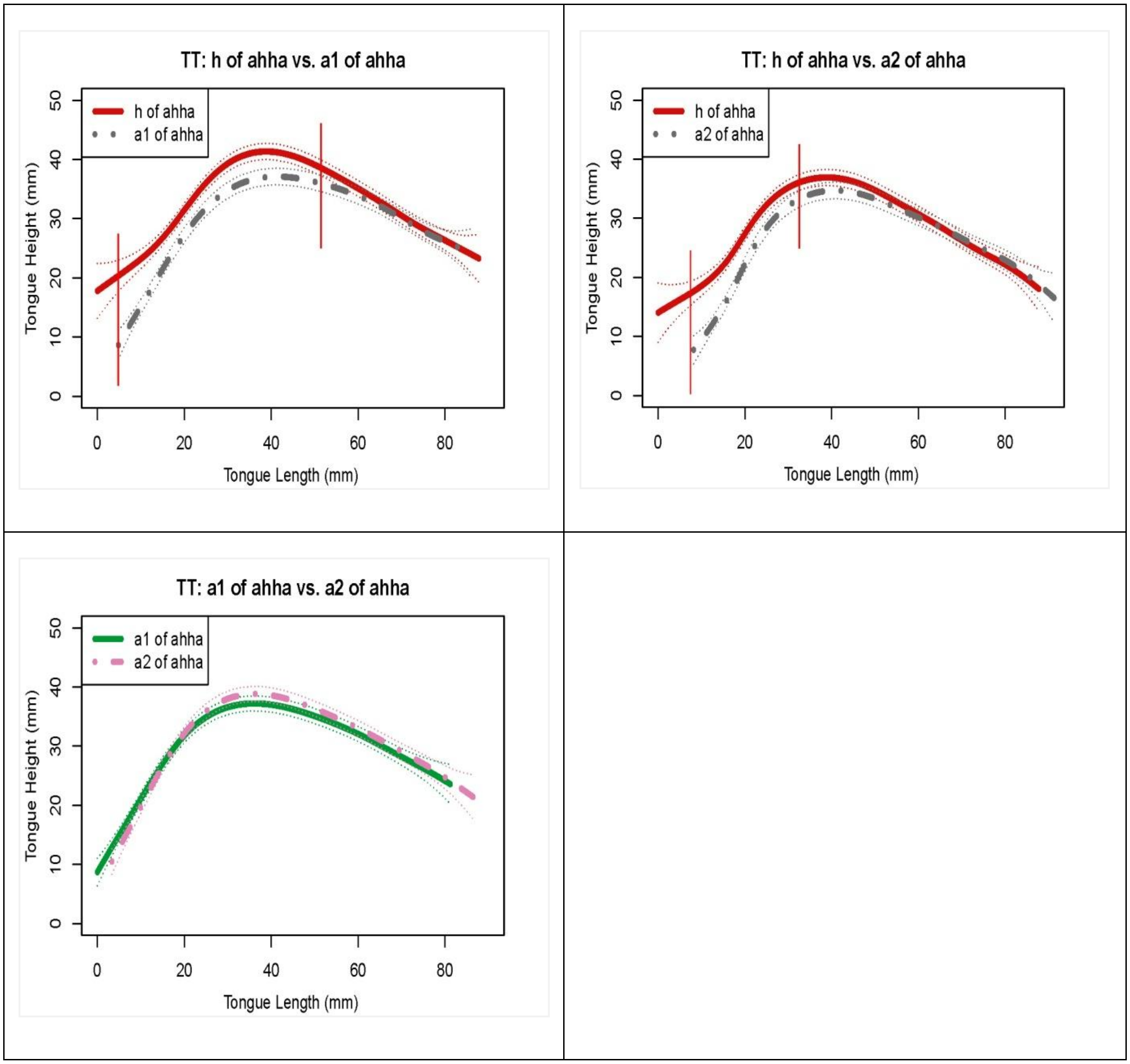


Figure 3.7. SS-ANOVA tongue-contour graphs: TT ahha

In speaker TT's production of /ahha/, shown above, /h/ is different from both a1 and a2. The constriction of /h/ is found in a relatively large area: from the mid dorsum to the posterior dorsum, where /h/ goes upward and gets retracted. There is no significant difference between a1 and a2.

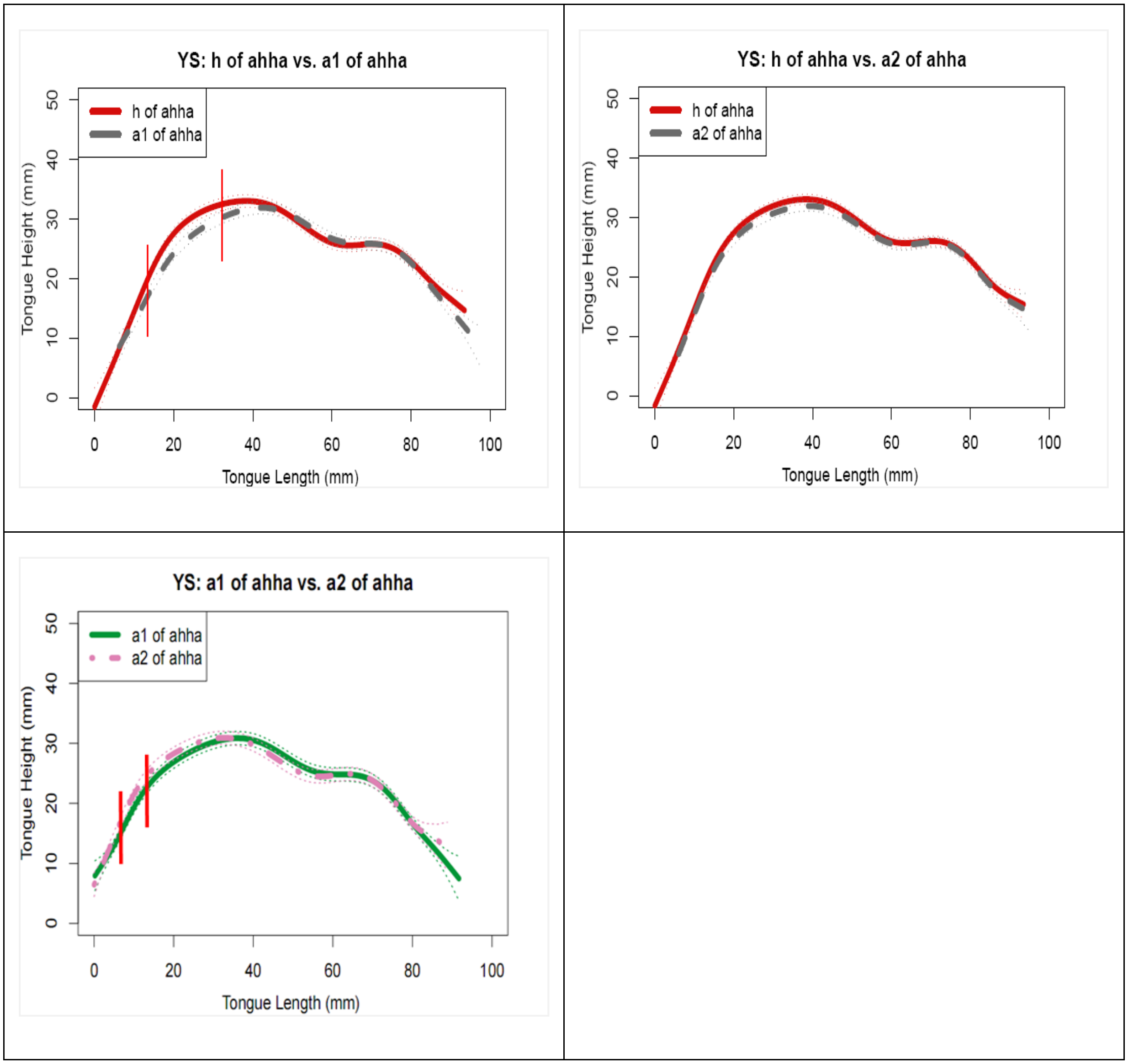


Figure 3.8. SS-ANOVA tongue-contour graphs: YS ahha

In speaker YS's production of /ahha/, shown above, /h/ is different from a1, but the same as a2. The constriction of /h/ is found on the posterior dorsum, where /h/ goes upward and gets retracted. There is a small region around the tongue root showing a significant difference between a1 and a2.

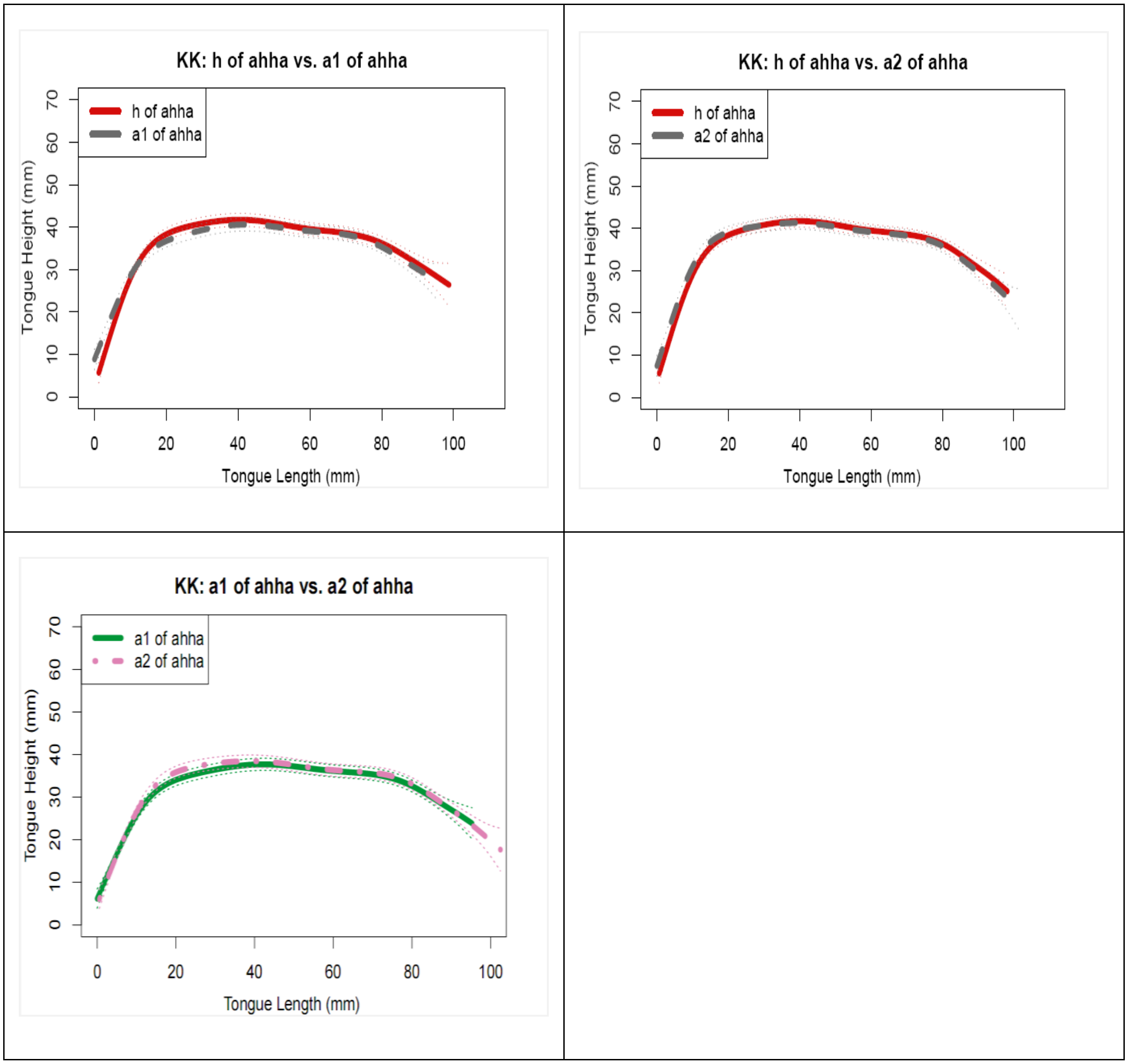


Figure 3.9. SS-ANOVA tongue-contour graphs: KK ahha

In speaker KK's production of /ahha/, shown above, /h/ is statistically not different either from a1 and a2. There is also no significant difference between a1 and a2.

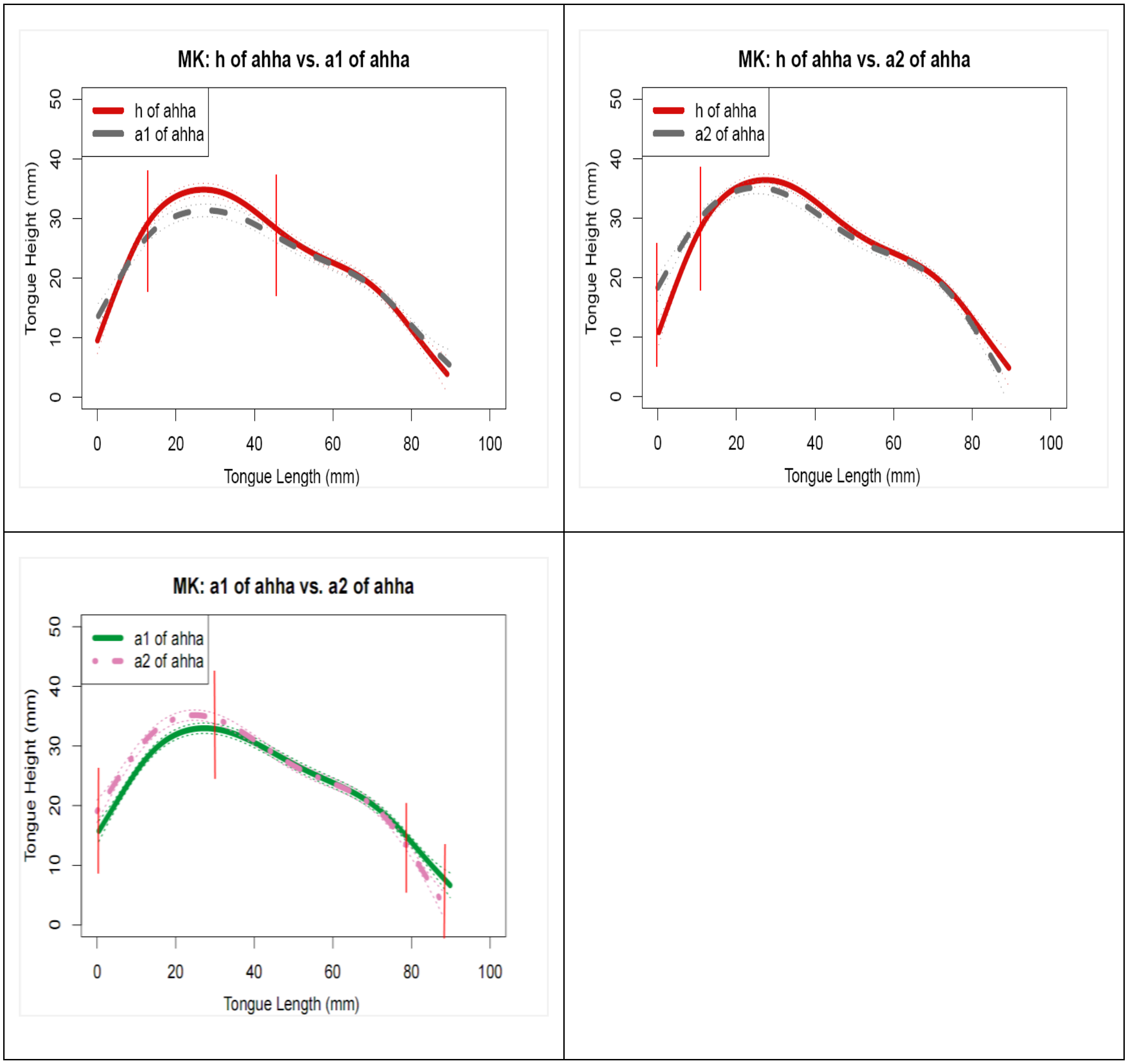


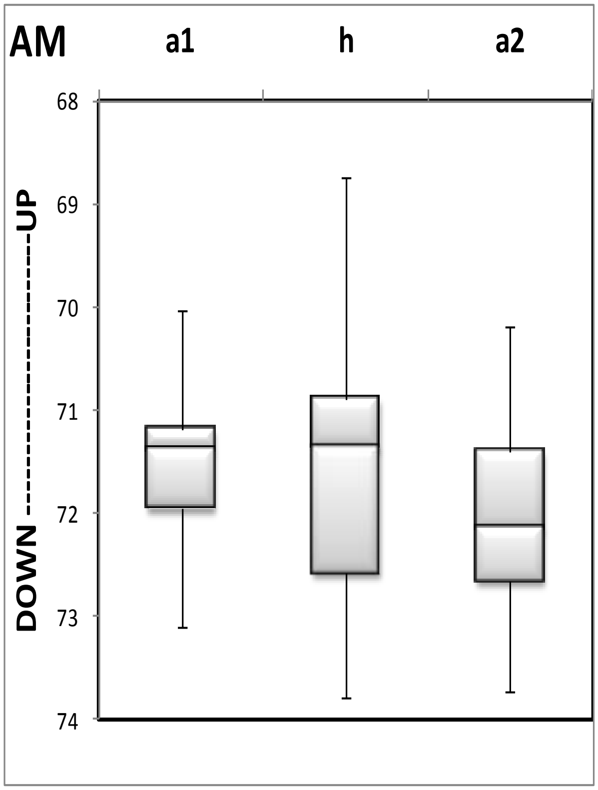
Figure 3.10. SS-ANOVA tongue-contour graphs: MK ahha

In speaker MK's production of /ahha/, shown above, /h/ is different from both a1 and a2. Compared to a1, the constriction of /h/ is found at the posterior dorsum, where we can see that /h/ moves upward. But when /h/ is compared to a2, the tongue root of /h/ is inside the tongue root of a2, rather than outside of it. a2 is significantly more retracted than a1 around the posterior dorsum to the tongue root.

The results suggest that HS and TT seem to have an independent target for /h/, since tongue raising of /h/ is significant compared to the /a/s on either side. Complete identity of /h/ with the flanking vowels is found in KK, which suggests that KK's /h/ has no target. MK's /h/ raises the tongue dorsum from a1 to /h/ while the tongue root goes forward from /h/ to a2. AM and YS's /h/s show a significant tongue raising compared to a1, but are identical to a2. Thus the interpretation of AM and YS's /h/ could be ambiguous. This issue will be discussed in section 3.4.

3.3.2. Constriction Degree

The graphs in this section show the constriction degree (values of y-axis; henceforth CD) of the peak of the tongue for each of a1, /h/, and a2 in /ahha/. The results show that two (HS, TT) out of six speakers have a significant raising of /h/ compared to both a1 and a2.

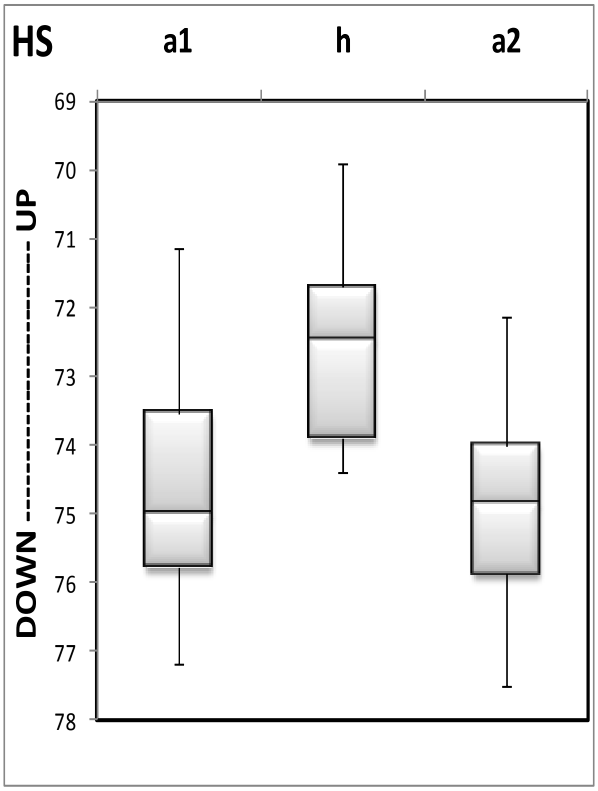


Labels	a1	h	a2
Mean	71.55	71.57	72.08
SD	1.02	1.33	1.06
Min	70.02	68.74	70.18
Q1	71.18	70.8825	71.3975
Median	71.38	71.355	72.145
Q3	71.945	72.5725	72.66
Max	73.89	73.79	73.72
IQR	0.765	1.69	1.2625

AM-y P-value (t-test)	
a1 vs. h	0.98
h vs. a2	0.31
a1 vs. a2	0.23

Figure 3.11. Boxplots of constriction degree: AM ahha

In speaker AM’s production of /ahha/, shown above, there is no significant difference between any pair of segments. The P-value indicates /h/ is not so different from /a/ on both sides. The mean values show that the tongue peak of /h/ is 0.02 mm lower than that of a1, and the tongue peak of a2 goes 0.51 mm lower than that of /h/. Since the mean of /h/ is between the mean of a1 and the mean of a2, this /h/ may be interpreted as being interpolative in terms of CD.

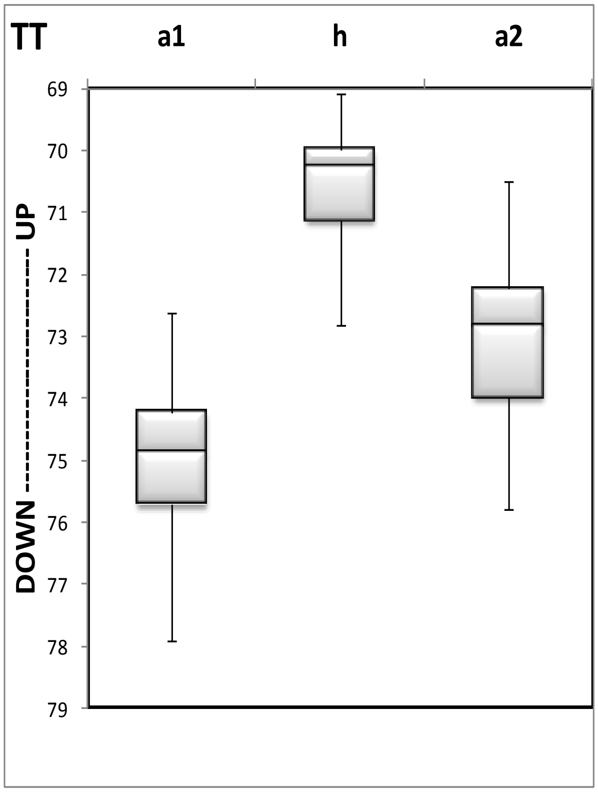


Labels	a1	h	a2
Mean	74.64	72.58	74.94
SD	1.77	1.48	1.49
Min	71.13	69.91	72.13
Q_1	73.5375	71.705	74
Median	75.01	72.47	74.865
Q_3	75.7675	73.8825	75.8675
Max	77.18	74.38	77.49
IQR	2.23	2.1775	1.8675

HS-y P-value (t-test)	
a1 vs. h	0.0054
h vs. a2	0.0008
a1 vs. a2	0.66

Figure 3.12. Boxplots of constriction degree: HS ahha

In speaker HS's production of /ahha/, shown above, there is a significant difference between a1 vs. /h/ and /h/ vs. a2. The mean values show that the tongue peak of /h/ is 2.06 mm higher than that of a1, and 2.35 mm higher than that of a2. In this case, /h/ is significantly higher than both a1 and a2, so this /h/ can be interpreted as having an independent CD.

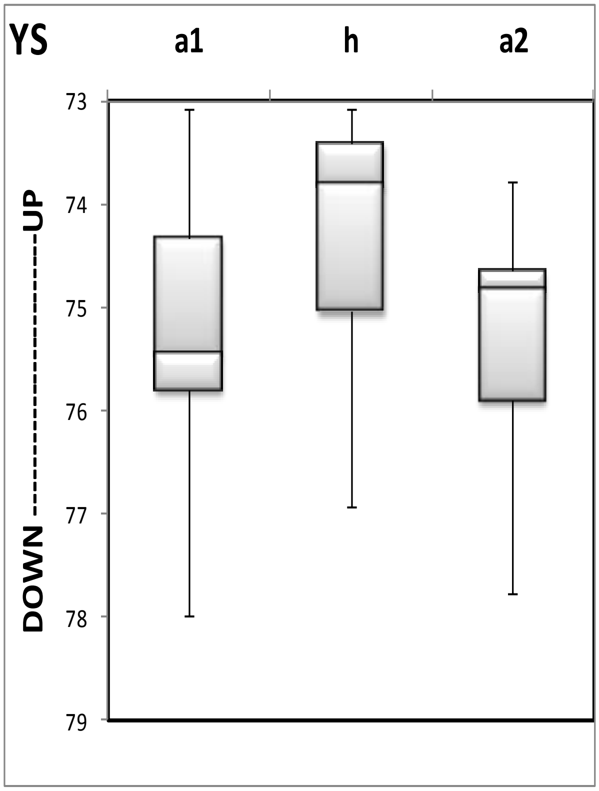


Labels	a1	h	a2
Mean	74.92	70.62	73.08
SD	1.57	1.17	1.64
Min	72.62	69.08	70.5
Q_1	74.2325	69.9875	72.235
Median	74.88	70.265	72.835
Q_3	75.7	71.125	73.975
Max	78.07	73.21	75.78
IQR	1.4675	1.1375	1.74

TT-y P-value (t-test)	
a1 vs. h	0.0001
h vs. a2	0.0003
a1 vs. a2	0.01

Figure 3.13. Boxplots of constriction degree: TT ahha

In speaker TT's production of /ahha/, shown above,, /h/'s tongue peak is higher than /a/ on both sides. Also, there is a significant difference between every pair of segments. The mean values show that the tongue peak of /h/ is 4.30 mm higher than that of a1, and 2.46 mm higher than that of a2. Since both differences are significant, this /h/ should be considered as having an independent CD.

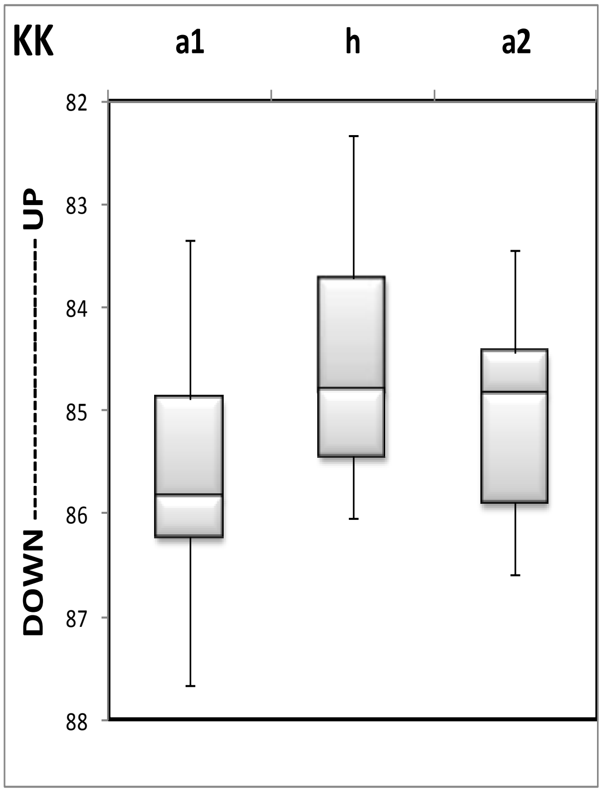


Labels	a1	h	a2
Mean	75.34	74.31	75.35
SD	1.31	1.19	1.21
Min	73.07	73.07	73.78
Q_1	74.3375	73.4125	74.65
Median	75.465	73.82	74.835
Q_3	75.8	75.0275	75.9
Max	78.03	76.92	78.14
IQR	1.4625	1.615	1.25

YS-y P-value (t-test)	
a1 vs. h	0.056
h vs. a2	0.045
a1 vs. a2	0.99

Figure 3.14. Boxplots of constriction degree: YS ahha

In speaker YS's production of /ahha/, shown above, the difference between /h/ vs. a2 is significant before the adjustment of the P-value. The P-value of a1 vs. /h/ (0.056) is also close to a significant difference. But after the adjustment of the P-value based on Bonferroni, both of them are no longer significantly different. The mean values show that the tongue peak of /h/ is 1.03 mm higher than that of a1, and 1.04 mm higher than that of a2. This /h/ may not be considered as having an independent CD.

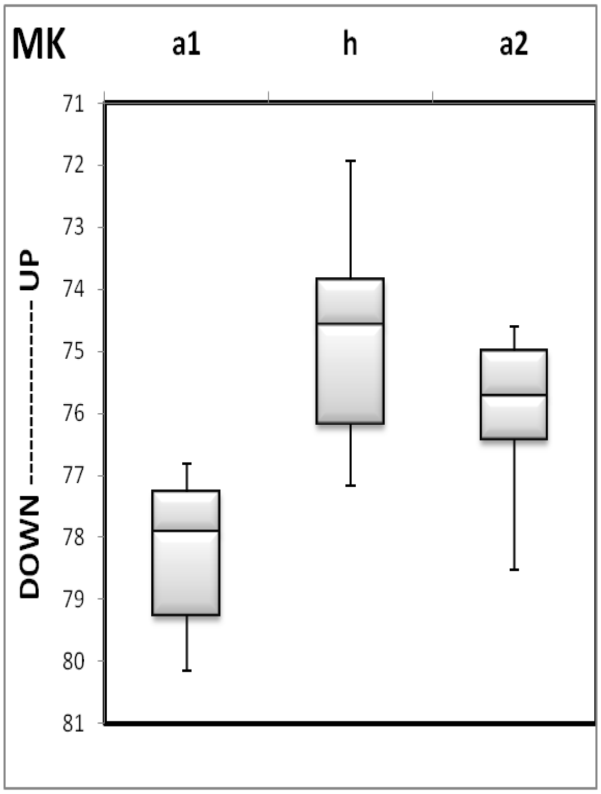


Labels	a1	h	a2
Mean	85.63	84.57	85.08
SD	1.27	1.08	0.962
Min	83.34	82.33	83.43
Q_1	84.8775	83.72	84.4325
Median	85.845	84.805	84.835
Q_3	86.2225	85.4325	85.8875
Max	87.66	86.04	86.58
IQR	1.345	1.7125	1.455

KK-y P-value (t-test)	
a1 vs. h	0.038
h vs. a2	0.24
a1 vs. a2	0.24

Figure 3.15. Boxplots of constriction degree: KK ahha

In speaker KK's production of /ahha/, shown above, a significant difference is found between a1 vs. /h/, but after the adjustment of the P-value based on Bonferroni, this is no longer different. The mean values show that the tongue peak of /h/ is 1.06 mm higher than that of a1, and 0.51 mm higher than that of a2.



Labels	a1	h	a2
Mean	78.32	74.92	75.85
SD	1.26	1.63	1.09
Min	76.81	71.93	74.59
Q_1	77.2675	73.845	74.9975
Median	77.925	74.575	75.725
Q_3	79.2575	76.1625	76.4125
Max	80.15	77.17	78.52
IQR	1.99	2.3175	1.415

MK-y P-value (t-test)	
a1 vs. h	0.0001
h vs. a2	0.11
a1 vs. a2	0.0001

Figure 3.16. Boxplots of constriction degree: MK ahha

In speaker MK's production of /ahha/, shown above, a significant difference is found between a1 vs. /h/ and a1 and a2. The mean values show that the tongue peak of /h/ is 3.40 mm higher than that of a1, and 0.93 mm higher than that of a2.

Whether the CD is significantly different from that of a1 or a2 was examined on t-tests. The result is summarized below.

Table 3.1. T-test results (unpaired): constriction degree of a1, h, a2 of *ahha* (P-values)

t-test	AM	HS	TT	YS	KK	MK
a1 vs. *h*	0.98	0.0054	0.0001	0.056	0.038	0.0001
h vs. a2	0.31	0.0008	0.0003	0.045	0.24	0.11
a1 vs. a2	0.23	0.66	0.01	0.99	0.24	0.0001

The results show that speakers can be roughly categorized into three groups:

(3.4) Three types of phonetic realization for constriction degree of /h/ (based on t-tests)

a. Not significantly different from a1 and a2: AM, YS, KK

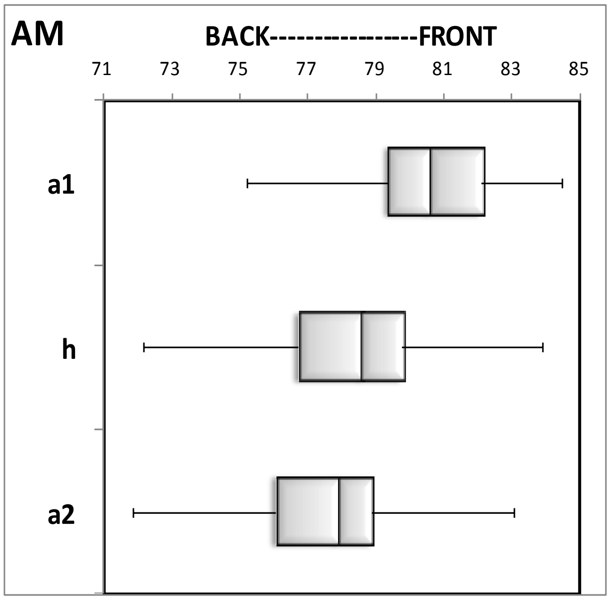
b. Significantly different from a1 and a2: HS, TT

c. Significantly different from only a1: MK

The group (3.4a) shows no significant difference in any of the pairs. AM obviously belongs to this group because both a1 vs. /h/ and /h/ vs. a2 show no significant difference. YS and KK also show this pattern, but only after the adjustment by the Bonferroni method. The targeted group (3.4b) shows a significant difference in both a1 vs. /h/ and /h/ vs. a2. As HS and TT show, the tongue body of /h/ is higher than that of both a1 and a2. The last group - MK - has /h/ that is significantly different from a1, but not from a2. Interestingly, it is found that HS and TT whose /h/s were categorized as pharyngeal also have a CD target.

3.3.3. Constriction Location

The graphs in this section show the CL (values of x-axis) of the peak of the tongue for each of a1 (the first [a]), /h/, and a2 (the second [a]) in /ahha/. The results show that four out of six speakers (AM, TT, YS, KK) have no significant difference between /h/ and either a1 or a2. Two speakers (HS, MK) show a significant difference between /h/ and a2.

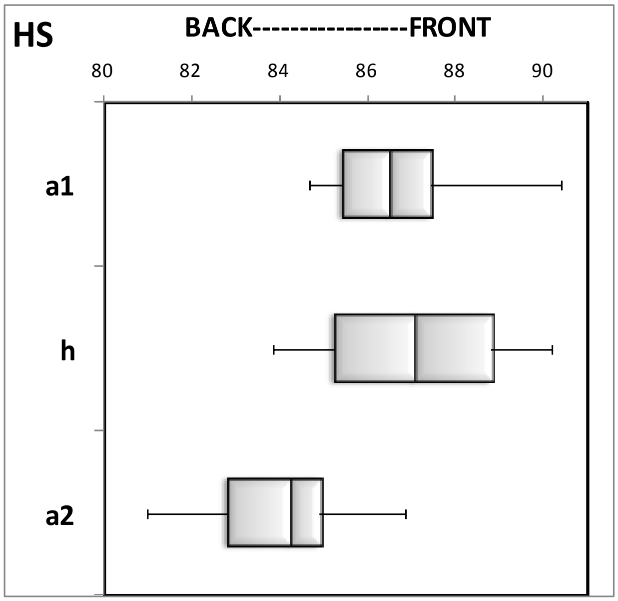


Labels	a1	h	a2
Mean	80.47	78.34	77.52
SD	2.57	3.02	2.85
Min	75.17	71.44	71.84
Q_1	79.385	76.7625	76.095
Median	80.605	78.6	77.91
Q_3	82.1325	79.805	78.8925
Max	84.53	83.94	83.26
IQR	2.7475	3.0425	2.7975

AM-x P-value (t-test)	
a1 vs. h	0.076
h vs. a2	0.50
a1 vs. a2	0.014

Figure 3.17. Boxplots of constriction location: AM ahha

In speaker AM's production of /ahha/, shown above, there is no significant difference between a1 vs. /h/ and /h/ vs. a2. (Though it is not our concern, there is a significant difference between a1 vs. a2). The mean values show that the tongue peak of /h/ is 2.13 mm farther back than that of a1, and the tongue peak of a2 is 0.82 mm farther back than that of /h/.

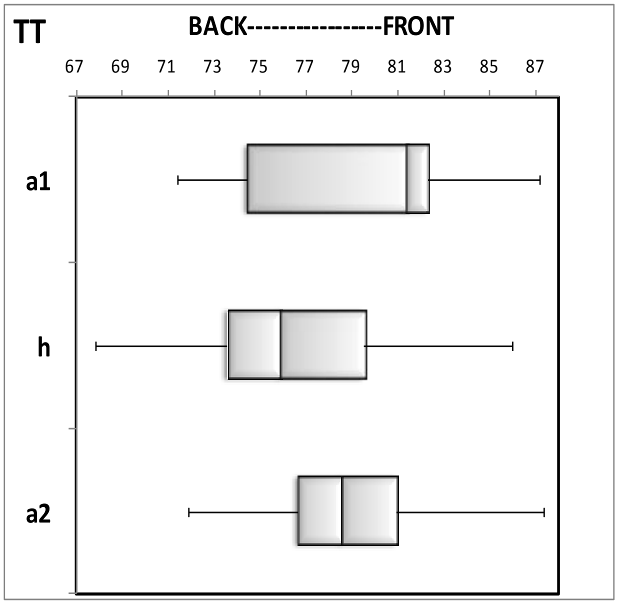


Labels	a1	h	a2
Mean	87.51	87.18	84.00
SD	0.8	2.12	1.60
Min	84.71	83.88	81
Q_1	85.4475	85.2725	82.8375
Median	86.515	87.1	84.255
Q_3	87.4475	88.82	84.92
Max	98.91	90.23	86.89
IQR	2	3.5475	2.0825

HS-x P-value (t-test)	
a1 vs. h	0.8
h vs. a2	0.0004
a1 vs. a2	0.0076

Figure 3.18. Boxplots of constriction location: HS ahha

In speaker HS's production of /ahha/, shown above, there is a significant difference between /h/ and a2 (and a1 vs. a2). The mean values show that the tongue peak of /h/ is 0.33 mm farther forward than that of a1, and the tongue peak of a2 is 3.18 mm farther back than that of /h/.

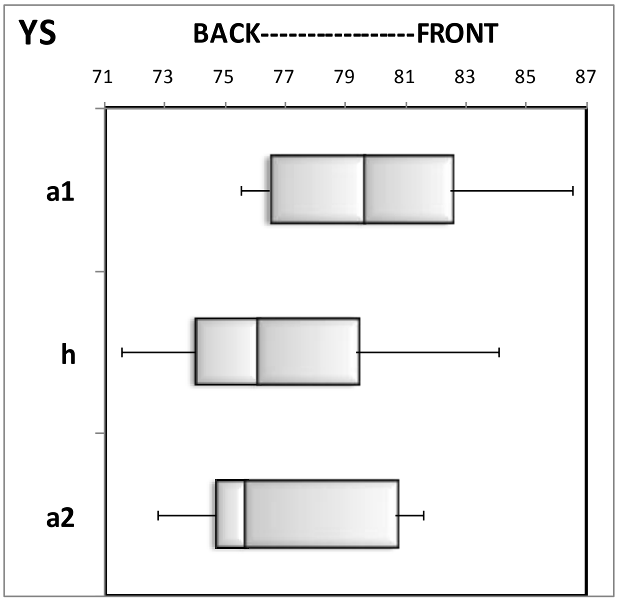


Labels	a1	h	a2
Mean	79.26	76.86	78.79
SD	4.9	5.04	4.22
Min	71.45	67.91	71.92
Q_1	74.4575	73.615	76.67
Median	81.39	75.885	78.59
Q_3	82.3175	79.5525	80.9525
Max	87.22	86.03	87.6
IQR	7.86	5.9375	4.2825

TT-x P-value (t-test)	
a1 vs. h	0.25
h vs. a2	0.32
a1 vs. a2	0.8

Figure 3.19. Boxplots of constriction location: TT ahha

In speaker TT's production of /ahha/, shown above, there is no significant difference between any of the pairs. The mean values show that the tongue peak of /h/ is 2.4 mm farther back than that of a1, and the tongue peak of a2 is 1.93 mm farther forward than that of /h/. /h/ is farther back than a1 and a2.

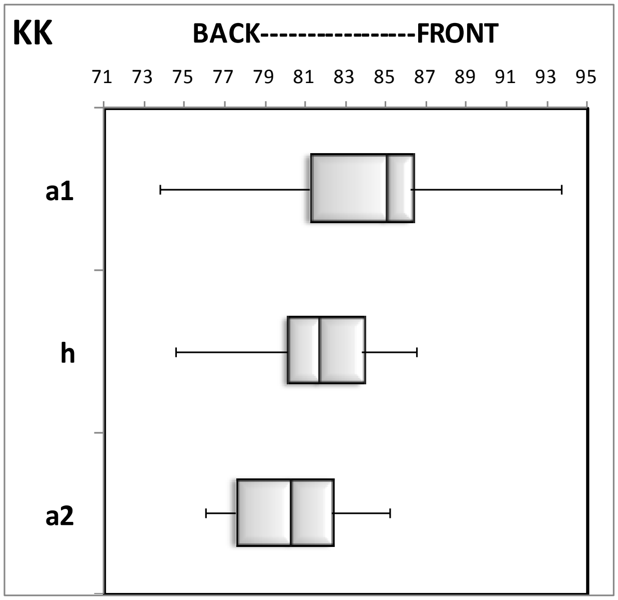


Labels	a1	h	a2
Mean	80.19	76.64	77.04
SD	3.81	3.9	3.28
Min	75.55	71.59	72.79
Q_1	76.5225	74.03	74.705
Median	79.605	76.08	75.67
Q_3	82.5225	79.3775	80.685
Max	86.54	84.13	81.62
IQR	6	5.3475	5.98

YS-x P-value (t-test)	
a1 vs. h	0.034
h vs. a2	0.79
a1 vs. a2	0.041

Figure 3.20. Boxplots of constriction location: YS ahha

In speaker YS's production of /ahha/, shown above, there seems to be a significant difference between a1 vs. /h/ and a1 vs. a2, but after the adjustment of the P-values by the Bonferroni method, they are no longer different. The mean values show that the tongue peak of /h/ is 3.55 mm farther back than that a1, and the tongue peak of a2 is only 0.4 mm farther forward than that of /h/.



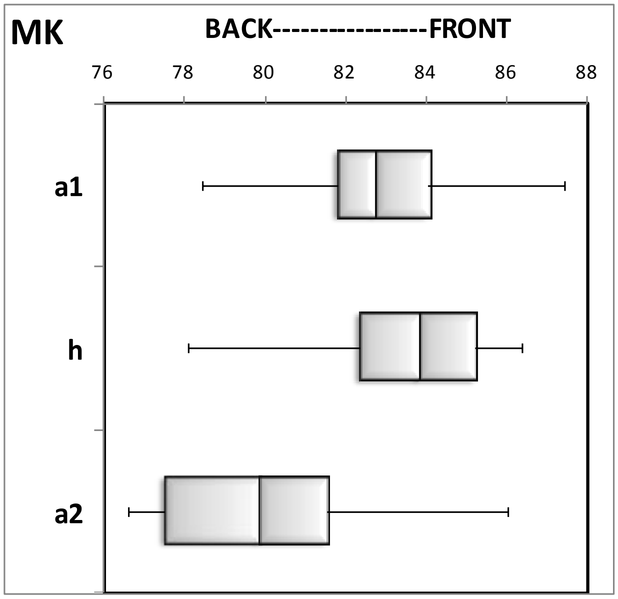
Labels	a1	h	a2
Mean	85.08	81.59	80.28
SD	8.45	3.45	3.11
Min	71.66	74.6	76.1
Q_1	81.29	80.15	77.5975
Median	85.085	81.715	80.285
Q_3	86.2875	83.855	82.3225
Max	107.3	86.57	85.21
IQR	4.9975	3.705	4.725

KK-x P-value (t-test)	
a1 vs. h	0.2
h vs. a2	0.34
a1 vs. a2	0.079

Figure 3.21. Boxplots of constriction location: KK ahha

In speaker KK's production of /ahha/, shown above, there is no significant difference between any of the pairs. The mean values show that the tongue peak of /h/ is 3.49 mm farther back than that of a1, and the tongue peak of a2 goes 1.3 mm farther back than that of /h/. In this case, the mean of /h/ is between the mean of a1 and the mean of a2, so /h/ may be interpreted as interpolative in terms of location.[46]

[46] Another possibility for KK is that /h/ and /a/ share a pharyngeal CL. This is supported by two observations: i) KK's CD for /h/ is not significantly different from the adjacent Vs, and ii) KK's tongue configuration looks flat, but the tongue root looks retracted.



Labels	a1	h	a2
Mean	83.03	83.38	80.10
SD	2.76	2.64	3.25
Min	78.37	76.78	76.63
Q_1	81.83	82.385	77.5275
Median	82.75	83.845	79.85
Q_3	84.08	85.2225	81.55
Max	87.92	86.42	86.06
IQR	2.25	2.8375	4.0225

MK-x P-value (t-test)	
a1 vs. h	0.75
h vs. a2	0.013
a1 vs. a2	0.027

Figure 3.22. Boxplots of constriction location: MK ahha

In speaker MK's production of /ahha/, shown above, there is a significant difference between /h/ and a2 (and a1 vs. a2). The mean values show that the tongue peak of /h/ is 0.35 mm farther forward than that of a1, and the tongue peak of a2 is 3.28 mm farther back than that of /h/.

Whether the CL is significantly different from that of a1 or a2 was examined on t-tests. The result is summarized Table 3.2.

Table 3.2. T-test (unpaired) of constriction location for a1, h, a2 of *ahha* (P-values)

	AM	HS	TT	YS	KK	MK
a1 vs. *h*	0.076	0.8	0.25	0.034	0.2	0.75
h vs. a2	0.50	0.0004	0.32	0.79	0.34	0.013
a1 vs. a2	0.014	0.0076	0.8	0.041	0.079	0.027

I consider that the evidence is solid for a categorical CL target for /h/, if both a1 vs. /h/ and /h/ vs. a2 are significantly different after the adjustment by the Holm-Bonferroni method. As Table 3.2. shows, none of the speakers show the pattern for the targeted CL (constriction location). The attested patterns are the two groups in (3.5):

(3.5) Two types of phonetic realization for constriction location of /h/ (t-test)

a. Not significantly different from a1 and a2: AM, TT, YS, KK

b. Significantly different from only a2: HS, MK

The group (3.5a) - AM, TT, YS and KK - shows no significant difference in either a1 vs. /h/ or /h/ vs. a2, so this group may be called CL-targetless group. The group (3.5b) - HS and MK - shows a significant difference between /h/ vs. a2, but not between /h/ vs. a1. No strong evidence suggests that /h/ has an independent CL target for anybody. But the measurement point here is the tongue dorsum rather than the tongue root. Thus, the non-significance of the difference among /a1, h, a2/ here simply means that horizontal movement was not found for the dorsum. This is expected if /h/ has a pharyngeal place, because the tongue dorsum and the tongue root can move independently.

3.3.4. Summary of Results

The previous sections examined whether /h/ has an independent target, by the comparison of /h/ with a1 and with a2 in /ahha/. SS-ANOVA examined the tongue configuration (section 3.3.1.). Furthermore, in order to detect whether the difference is for CD or CL, y-values (section

3.3.2.) and x-values (section 3.3.3.) of the tongue peaks were compared in boxplots. The table below shows the results on each criterion for all speakers.

Table 3.3. Combined results of SS-ANOVA and boxplots: ahha

	Tongue Configuration	Constriction Degree	Constriction Location
AM	=a2	~~=a1&a2~~	~~=a1&a2~~
HS	diff	diff	=a1 (/h/ is anterior to a2)
TT	diff	diff	~~=a1&a2~~
YS	=a2	~~=a1&a2~~	~~=a1&a2~~
KK	~~=a1&a2~~	~~=a1&a2~~	~~=a1&a2~~
MK	diff	=a2	=a1 (/h/ is anterior to a2)

The green cells suggest that there are significant differences both between /h/ and a1 and between /h/ and a2. The cells with horizontal lines indicate no significant difference in any of the pairs.

For /h/ to be pharyngeal, a significant difference does not have to appear in every column. If /a/ and /h/ are both pharyngeal, then we would *not* expect them to have independent CLs. The crucial points, therefore, seem to be tongue configuration and CD. This prediction is compatible with numerous analyses of feature structure that would predict no significant differences in CL (McCarthy 1994, Cole 1987).

Thus, HS's and TT's /h/ are likely to be pharyngeal, as the results of tongue configuration as well as CD suggest. Although MK's tongue configuration shows that /h/ has significant differences in comparison to /a/ on both sides, it is less likely to be pharyngeal, because compared to a2, /h/ is inside the line of a2 rather than outside of it. KK's /h/ shows no significant difference anywhere, suggesting that it has no independent target. The other speakers – AM and YS – are assimilation-type, which will be discussed in the next section.

3.4. Discussion

3.4.1. Assimilation-Type /h/

In previous sections, I have tried to categorize the observed types as either placeless or pharyngeal. In this section, I discuss the cases which may allow an ambiguous interpretation in the phonological representation. The assimilation-type /h/, where the phonetic realization of /h/ has a complete identity to either V1 or V2, is one case.[47] This type could be ambiguously interpreted as either *dorso-pharyngeal* or *pharyngeal*, and I show some reasons.

The SS-ANOVA of this assimilation-type which is observed in AM's and YS's speech is given below.

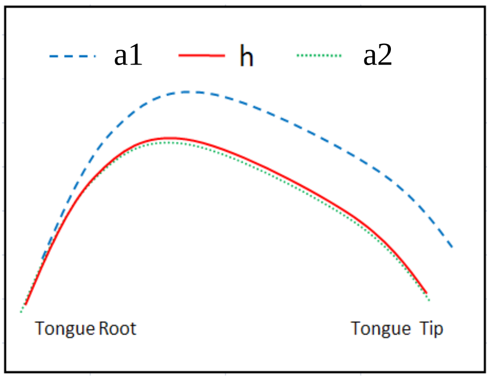


Figure 3.23. Assimilation-type /h/

In this figure, /h/ is statistically identical to a2. When SS-ANOVA produces such a pattern, this can be taken as phonological assimilation.

[47] Notice that all the assimilation-type /h/s here are statistically identical to a2 rather than to a1. This is predicted from the coupled oscillator model of syllable structure developed by Goldstein, Chitoran and Selkirk (2007). It posits that the onset consonants have an in-phase coupling relation with the following vowel, while coda consonants have an anti-phase coupling relation with the preceding vowel. Thanks to Alexei Kochetov.

Since we observe how /h/ behaves relative to /a/, it seems necessary to set up some feature for /a/ as a guideline to compare with /h/. The assumption of the featural content for /a/ varies across researchers, and at least i) dorsal, ii) pharyngeal, or iii) dorsal and pharyngeal seem possible. But here I will assume that Japanese /a/ is basically [dorsal].[48] This is a plausible assumption from the Japanese phonotactic patterns: In palatalization, a high front glide can be followed by a back vowel /(C)ja, (C)ju, (C)jo/, but not by a front vowel /*(C)ji, *(C)je/. Here the asymmetry can be explained if /a/ is assumed to be a back vowel (Mester & Itô 1989, Alderete & Kochetov 2009). Also, in the constriction-based model of feature geometry (Clements & Hume 1995), [dorsal] is defined as "involving a constriction formed by the back of the tongue" (ibid.: 277).

If we assume [pharyngeal] for /a/, there are some problems. For the speakers who have pharyngeal /h/, we need an additional specification for pharyngeal /h/, otherwise /a/ and /h/ would become completely identical. A common solution is to distinguish them by a higher node of V-place and C-place (Clements & Hume 1995). Even if the solution seems useful, we need phonological evidence to distinguish /a/ from the other back vowels /u, o/. Furthermore, if /a/ is pharyngeal, an additional account is needed for why the crosslinguistically disfavored sequence of high vowel and pharyngeal - (C)ja - is allowed in palatalization in Japanese. Thus I proceed in the discussion below based on the assumption that /a/ is [dorsal] in Japanese.

Supposing that /a/ is [dorsal], we still need to account for the retraction of a2, which shows a significant difference from a1. One account is to ascribe the retraction of a2 to some feature/property inherent in a2 itself, and the other one is that a2 acquires some retraction feature/property from the preceding /h/. I will describe both possibilities below.

There is a reason that the retraction may be inherent in a2. The vowel a1 has a high tone, while a2 has a low tone in the stimuli used for this experiment. It has been pointed out that low tone lowers the larynx height (Erickson, Baer and Harris 1983). Erickson et al. (1983) found that the cricothyroid muscle must relax before the larygeal muscles (strap muscles) can participate in

[48] Phonetically, the backness of /a/ may be indeterminate. It is uncontroversial that /a/ is the only low vowel in Japanese, but whether it is back or front in the vocalic space may depend on the speaker. Akamatsu (1997: 34-35) states, based on his own pronunciation, the highest point of the tongue is on the central part of the tongue, but he also admits that the position of /a/ varies from nearer to the cardinal vowel No.4 [a] (most fronted) to near to No.5 [ɑ] (most backward) depending on the speaker.

F0 falling, and the activity of the cricothyroid is more active during the shift from a high tone to a low tone, compared to the shift from a mid tone to a low tone. All the words used in the current experiment were disyllabic, where the first syllable has a high tone and the second one has a low tone. So the tone pattern of the words used in the current experiment fits with what is expected. Furthermore, Honda (1983) reports that as F0 rises, the tongue root (and the hyoid bone) advances, which results in a wider pharyngeal cavity. A similar result was revealed for a Japanese male speaker in Takemoto, Kitamura, Honda & Masaki (2008).

Trigo (1991:115) and Meechan (1992: 109, 114) expressed the view that the feature involving pharyngeal expansion, or what Lindau (1979) calls [expanded pharynx], needs more investigation crosslinguistically, and suggest the features [lowered larynx] and [ATR] may be independent. Thus some feature, as a concomitant feature of low tone, can be introduced to a2. But I do not use [lowered larynx] or [ATR] because the relation is not clear in my data. What is observed here is that a2 is retracted compared to a1 which has the feature [dorsal]. In fact, /a/ has been claimed to be [pharyngeal] (McCarthy 1988, Hayward and Hayward 1989, E. Pulleyblank 1989, Lombardi 2002, Mudzingwa 2010), so I could introduce this feature to low-toned /a/ as a dependent feature of [dorsal], representing the output as dorso-pharyngeal. In this way, the difference is marked with [pharyngeal], while the phonemic identity is shown with [dorsal]. If this is correct, the output representation would look like this:

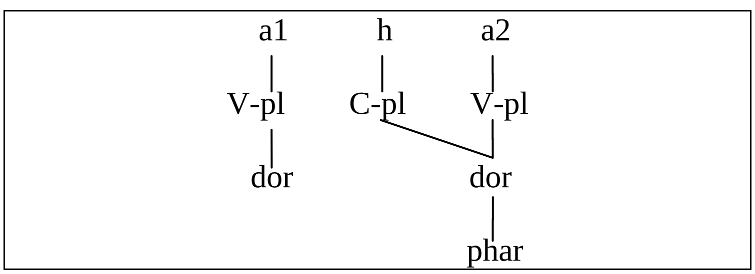


Figure 3.24. Identity between /h/ and a2: Trigger is a2

It is not important that [phar] is a dependent of [dor]. Instead, [phar] could be a dependent of V-pl. The spreading or delinking of association lines, which are conventionally indicated, are omitted, as the derivational process is not important here. The focus should be laid on the output only. In this structure, /h/ and a2 share the feature dorso-pharyngeal. But this is just a speculation, as it is not really clear whether the two low vowels need a phonological difference (other than tone) to be specified.

But if there can be an effect on how retracted they are based on tone, then one of the problems is that the observation here does not match with Nakajo (1989: 63). He observes impressionistically two allophones for /a/ depending on the tonal difference, citing the minimal pair [ɑ́me] ‘rain’ [ame] ‘candy’. As the symbols in the examples show, /a/ with a high tone implies tongue root retraction, and /a/ with a low tone implies tongue root advancement. These are exactly opposite from what was observed in my experiment, where /a/ with a high tone has an advanced tongue root, and /a/ with a low tone has a retracted tongue root. Furthermore, even though SS-ANOVA catches a significant difference between a1 and a2 and this difference exists, it might not really be large enough to warrant a phonological analysis. The difference in the tongue root may be just a phonetic consequence of the tonal differences, and whether it is phonological is inconclusive.

Another possible source of the retracted a2 is /h/. That is, a2 acquires [pharyngeal] from /h/. This is shown below.

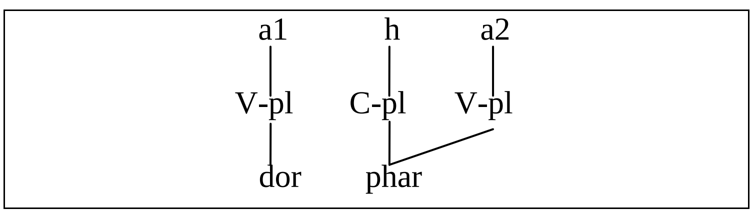


Figure 3.25. Identity between /h/ and a2: Trigger is /h/

In the figure above, it is assumed that [dor] under a2 gets delinked (the derivational process is omitted for convenience’s sake), but this is not a necessary assumption. Theoretically it is possible to retain [dor], and the output of a2 would have both [phar] and [dor]. In either case, [pharyngeal] would be shared by /h/ and a2 in the output, which is compatible with the /h/-as-pharyngeal analysis.

Below is the summary of types of /h/ across speakers:

(3.6) Summary of types of /h/: Preliminary analysis

AM	dorso-pharyngeal or pharyngeal
HS	pharyngeal
TT	pharyngeal
YS	dorso-pharyngeal or pharyngeal
KK	placeless or dorsal
MK	uncategorized

HS and TT's /h/s can be categorized as pharyngeal, because /h/ has tongue root retraction compared to both a1 and a2. AM and YS's /h/s can be dorso-pharyngeal or pharyngeal depending on which segment the trigger of the assimilation is: It may be dorso-pharyngeal if /h/ is assumed to assimilate to a2, or pharyngeal if a2 is assumed to assimilate to /h/. KK's /h/ can be analyzed as placeless (if interpolative) or dorsal (if assimilation).[49] MK is left uncategorized here, because according to the present analysis, there are only three criteria – i) pharyngeal-type /h/s, if /h/ is outside both a1 and a2 (HS, TT), ii) assimilation-type /h/s, if /h/ is outside from a1 but completely identical with only a2 (AM, YS), and iii) interpolation-type /h/s, if /h/ is on the trajectory from a1 to a2 (KK) - and MK does not fit to any of these criteria – /h/ is outside a1 only and is not identical with a2 (but later on in sec. 3.4.3. Finding Constriction Location by Template., I will modify this analysis, and PoA of MK is detected).

This section concludes by giving another piece of evidence that the /h/ of HS and TT is pharyngeal. In sec. 3.2.2.1. Selection, I have stated that /ihhi/ was not selected for analysis, because Japanese /h/ before /i/ is a palatal fricative, which is well established in Japanese phonology. But the /ihhi/ data shows interesting results: For TT and HS only, the posterior-dorsum to the tongue root is retracted in /h/ in this context as well. Interestingly, other speakers' /h/s show no significant difference in /h/ vs. /i/.

[49] It may be still possible to set up a different criterion, or a different methodology, to explore the pharyngeal/placeless distinction. For example, even KK might be making a constriction that is not happening in the mid-sagittal dimension (cf. Francis, Klenin, Mizrahi, Tom & Gick 2011), and therefore does not show up on ultrasound images.

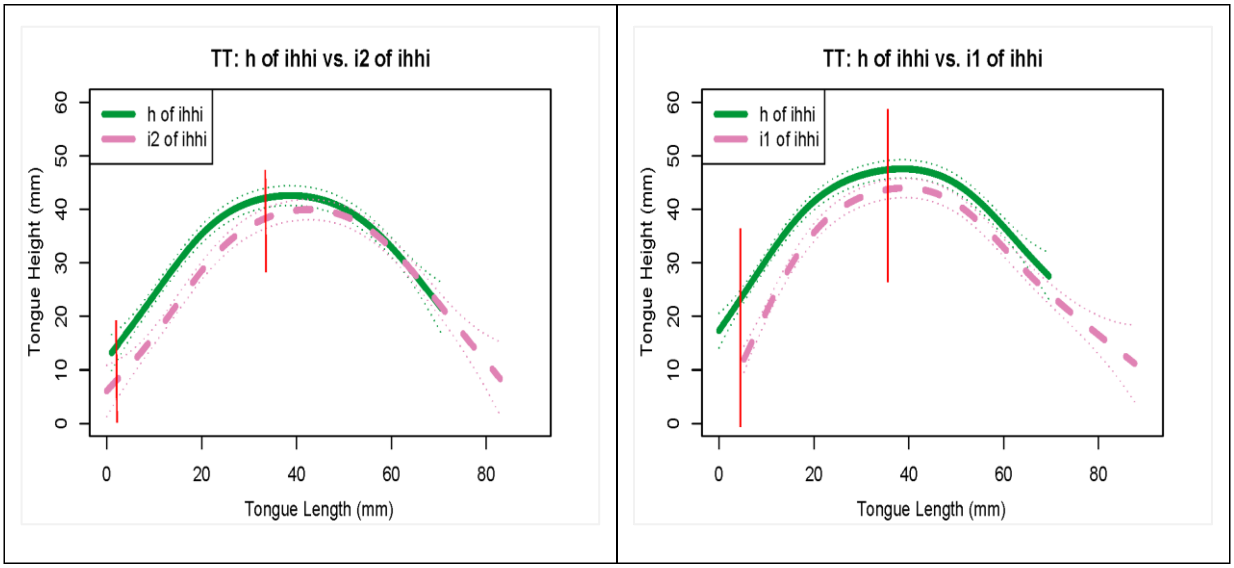


Figure 3.26. SS-ANOVA tongue-contour graph: TT /ihhi/

In TT's speech, the retraction area is observed in a region of the back part of the tongue around 18 mm in length. This retraction is significantly different from both i1 (ihhi) and i2 (ihhi). This /h/ can be considered as pharyngealized.

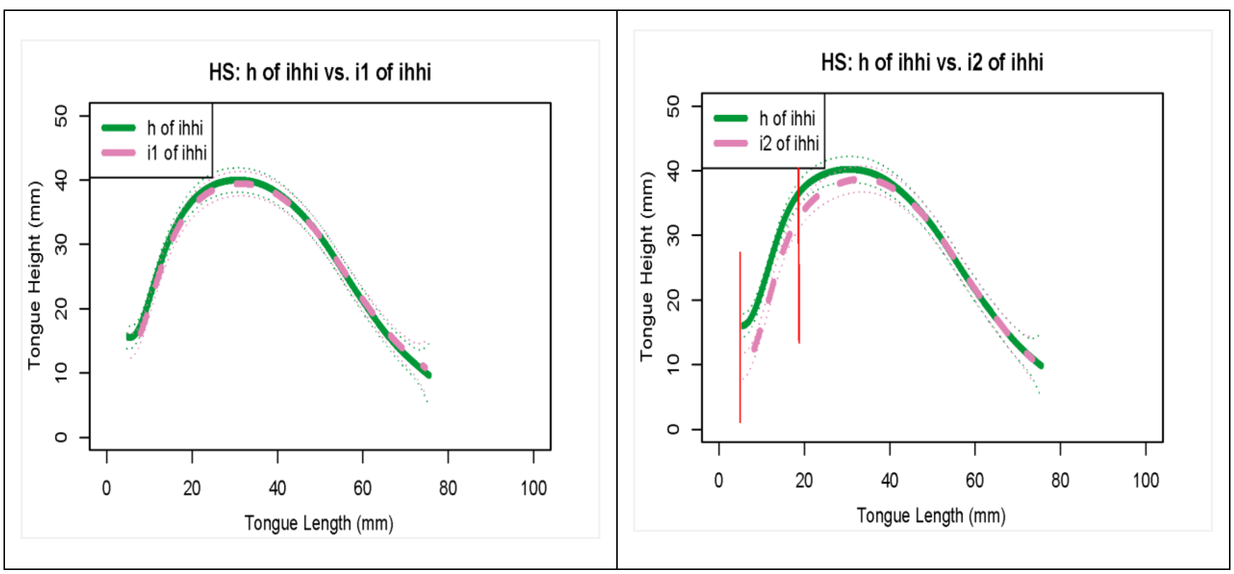


Figure 3.27. SS-ANOVA tongue-contour graph: HS /ihhi/

In HS's speech, /h/ is identical to i1, but is retracted relative to i2. (A bit of the tongue root data has been omitted from HS's data, because of artifacts: Some of the SS-ANOVA graphs of /ihhi/ accidentally show an anomalous curly tongue root. This probably happened at some stage of data processing in EdgeTrak or SS-ANOVA.)

What is interesting is that parallelism is seen in the /ahha/ and /ihhi/ data. Only the speakers who showed pharyngealization in /ahha/ show pharyngealization in /ihhi/ (For contour graphs of /ihhi/ for all speakers, see Figure B. 1 in Appendix). Based on the evidence, TT's /h/ makes a strong pharyngeal constriction in both the /a/ context and the /i/ context.

3.4.2. Individual Variation in the Representation of /h/

The results indicate that different individuals have different strategies in articulating /h/. The prediction that /h/ is not placeless turned out to be partly true, at least for some speakers.

Based on the attested results (especially from SS-ANOVA, with support from CD/CL of the tongue peak), the difference can be expressed by the autosegmental representations below. The symbols [α] and [β] denote some feature. In the discussion in this section, it does not matter which feature [α] and [β] stand for.

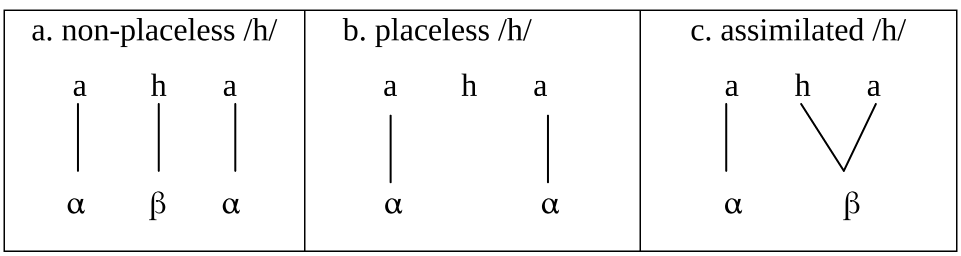


Figure 3.28. Representations of three types of /h/

The discussion here is about representations of three types of /h/ in Figure 3.28. Non-placeless /h/ or pharyngeal /h/ (a) is attested in HS and TT, placeless /h/ (b) is attested in KK, and assimilated /h/ (c) is attested in AM and YS. The overall results show that the place of /h/ is either unspecified, as in (b), or specified, as in (a, c). The correspondence between /h/ and the featural place specification is not uniform across speakers.

Some observations from the previous literature may affect the representations above. In particular, Kawakami (1977: 50) observes that [x] is optionally used for /h/ before nonhigh vowels, especially in laughs [axxaxxa], or surprise interjection [xoo]. Likewise, Okada (1999:

118) includes [xx], [çç] and [ɸɸ] for the realization of the geminate /h/. Since [x] is velar in IPA, the representation should be [dorsal] without [pharyngeal].

However, Akamatsu (1997: 97) brings up /χ/ as a frequently heard pronunciation for Japanese /h/ before nonhigh vowels. [χ] is "uvular" in IPA; in his terms it is a "voiceless dorso-uvular fricative", by which he means:

> …articulated with the soft palate in its raised position, with no vocal vibration, and the (voiceless) audible friction occurring <u>between the raised back of the tongue and the uvula</u>. [χ] should <u>not be confused with [x] (voiceless dorso-velar fricative)</u> which corresponds to 'ach-Laut' (i.e. ach-sound) – as in the Scottish word loch 'lake' pronounced [lɒx] – in the articulation of which the (voiceless) audible friction occurs between the back of the tongue and the soft palate. (emphasis N.Y.)

Also he states that "Substitution of [h] by [x] (voiceless dorso-velar fricative) should be avoided." (ibid. p.98). Clearly, he claims that the CL is not velar, and should be more back; thus his term "dorso-uvular" should not be purely [dorsal].

It seems that Kawakami's opinion and Akamatsu's opinion conflict with each other, but the distinction between velar and uvular is very difficult to judge using auditory impressions, at least when there is no velar/uvular distinction in a speaker's/hearer's language. Also, it does not matter which of the velar or uvular fricative is used for the purpose of communication, since native speakers of Japanese perceptually categorize them as /h/ in any case.[50]

In languages such as Semitic, where postvelar consonants are abundant, the distinction among those consonants is more crucial. Even within the same place class, some consonants behave asymmetrically. The following example is not a velar vs. uvular distinction, but I will raise the following examples to show that consonants behave asymmetrically even when they belong to the same place category. McCarthy (1991) argues that Semitic has two kinds of *uvulars* whose place features are different: one is the **guttural uvular** (i.e., the uvular fricative [χ]), which has a "Pharyngeal" node with dependents of [dorsal] and [pharyngeal]. Crucially, this should not be confused with the **back uvular** (i.e., uvular stop [q]), which consists of the

[50] Evidence should be able to be found using perceptual tests. See Sapir (1985[1933]) for the arguments for psychological reality of phoneme.

primary place node as Oral (with [dorsal]) and the secondary place node as Pharyngeal (with [pharyngeal]). The reason for this separation is that in Semitic, the uvular fricative patterns with pharyngeals and glottals, but the uvular stop patterns with oral consonants, in terms of cooccurrence restrictions. The evidence is from phonological patternings, but it is phonetically grounded as well.

In the Japanese situation, there is agreement that the place of /h/ is glottal, but the validity of such agreement is exactly what I am calling into question. This question should also be extendable to whether these pronunciations are canonical or optional for the speakers I have studied.

Uvular or velar may be an optional pronunciation in Japanese in general rather than the canonical one. If this is the case, I am not sure how much it is worth discussing the structure of an optional pronuciation. Trigo (1991) argues that there are two kinds of *uvulars*: one is purely **dorsal**, which consists of [-high, +back], and the other is **dorso-pharyngeal**, having Dorsum as the primary articulator and Pharynx as a secondary articulator with its dependent [Retracted Tongue Root] and [Raised Larynx]. My experimental results here are more compatible with the latter type of uvular, since the tongue root is retracted.

Different patterns suggest that the phonological grammar looks different among speakers. On the one hand, our prediction was correct. Since Japanese /h/ can be pharyngeal, the phonology of Japanese /h/ varies in its representation. This cannot be ascribed to dialectal differences, because they are all speakers of the same Tokyo dialect.

Japanese loanword phonology provides evidence for the view that /h/ may be left unspecified at the output of phonology. The default Japanese epenthetic vowel for loanwords is /u/ (e.g., rakku 'luck', kisu/kissu 'kiss', hooru 'hall'; however, after /h/, the epenthetic vowel has the same quality as the vowel preceded by /hh/ (e.g., bahha 'Bach', gohho 'Gogh' eerurihhi 'Ehrlich'). This can be interpreted as "echo epenthesis," derived by V-place spreading from the preceding vowel (Kawahara 2004, 2007). This analysis argues that the intervening /h/ can be transparent and lacks a place node (Steriade 1987a, Stemberger 1993).

But the lack of a place node is not crucial in capturing the transparency effect for the following reasons. It was already pointed out in the derivational framework that spreading can occur even if /h/ has a place node (see Rose 1996, Stemberger 1993). In the bifurcational feature geometry model where the place node consists of subnodes of Oral and Pharyngeal, a linecrossing constraint (Goldsmith 1976) would rule out spreading across consonants if the consonant is Oral. Vowels are Oral, so the spreading from Oral of V1 to V2 would interfere with the Oral node of the consonant. So this spreading cannot be allowed. But if the consonant has no place node, or has a Pharyngeal node, spreading of Oral from the vowel would be possible. In addition to such a representational approach, guttural transparency is typologically predicted in the constraint-based approach (Gafos & Lombardi 1999). So echo epenthesis is not a strong support for placeless /h/.

Another argument for placeless /h/ is the Coda Condition in Japanese (Itô 1986). But if [h] is placeless, as is claimed for /N/ in Japanese, then [bah] from 'Bach' [baχ] should be perfectly fine, and why does vowel epenthesis occur after [h]? The epenthesis can be argued for on the view that /h/ has pharyngeal place, which has to survive (Lombardi 2001).[51]

The possibility of multiple feature specifications as above may come from the phonetic ambiguity of /h/: it is classically dubbed as a 'fricative', implying it behaves like **consonants**, but could be a 'glide' (SPE) or 'approximant' (Keating 1988), implying it behaves more like **vowels** or expects interpolation. Such highly variable characteristics of /h/ may allow speakers to access different resolutions to the potential ambiguity. Interestingly, although multiple resolutions are available, as shown in Figure 3.28, the individual choice is found to be discrete and categorical.

3.4.3. Finding Constriction Location by Template

It is important to find where the CL is, though we can say the tongue root is retracted toward the pharyngeal area. One possible way to find the CL is to take the image of the palate of the individual speakers during swallowing, and take the point where the tongue is the closest to the palate. But this method was not adopted here, because I found a large amount of variability in the images of palate tracings that I made in EdgeTrak from several phases of one instance of swallowing for each person. The large variability of the surface of both the soft palate and the hard palate was already discussed in Epstein, Stone, Pouplier & Parthasarathy (2004). They observed (i) the *soft* palate shows variability due to the up and down movement during swallowing - for one subject, the range is 13.18 mm, for another, 11.91 mm - and (ii) the *hard* palate also shows variability for one subject; the range is 3.04 mm, for another, 6.19 mm. Thus,

[51] Thanks to Shigeto Kawahara for pointing this out.

for the speakers they observed, the variability of the soft palate is greater than the variability of the hard palate. This is not surprising if we consider the soft palate has no bone inside so that it is more flexible than the hard palate, which has a bone. In the images I took from one subject, somewhat larger variability is observed in the more posterior part of the palate, which makes the end of the velum unmeasurable.

Since we were not able to take the image of the palate due to the instability of the palate in swallowing, we could not apply the palate image over the tongue to examine where the tongue constriction is happening. However, a rough estimate is possible, by using a template.

The template was made in the following way. MRI images of two Japanese male speakers articulating the Japanese /a/ sound were used as models.[52] First, a base line was drawn from the tip of the tongue to the root of the tongue.[53] Second, a line was drawn from the midpoint of the base line to the end of the velum. Third, a line was drawn from the midpoint of the base line to the beginning of the velum. Now we see the oral tract is divided into three blocks.

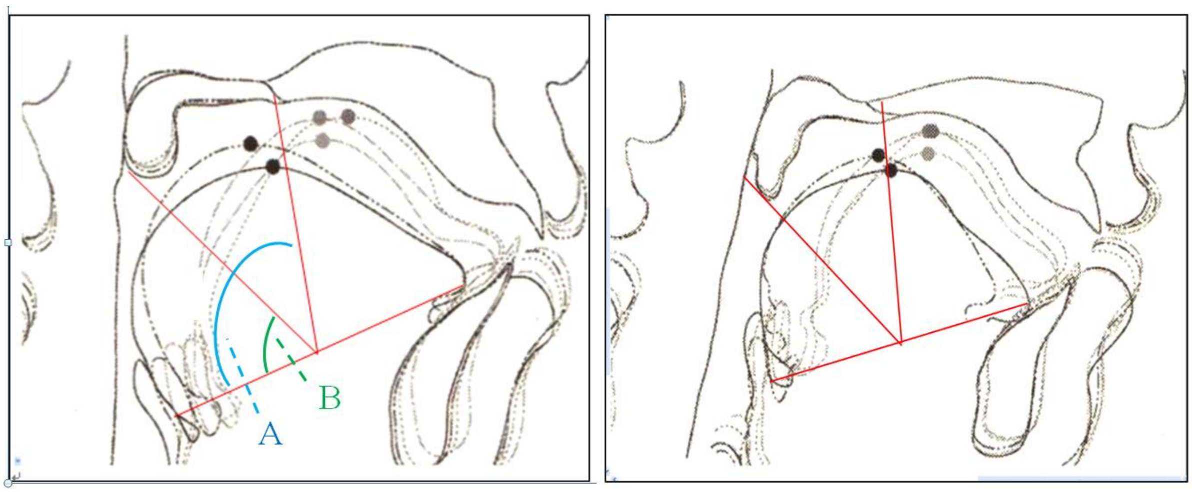


Figure 3.29. Line drawing based on MRI images of Japanese /a/ of Zhu and Hatano (2010)

[52] It is important to use MRI images of Japanese speakers, as there may be relevant anatomical traits specific to Asians (cf. Hiki and Itoh 1986).

[53] Measurements based on the tongue tip and root may be taken as just estimates rather than absolute figures, as the edges of the tongue tip and root are subject to change. See Ménard, Aubin, Thibeault, & Richard (2012) for another kind of measurement based on the tongue tip and root. They use a triangle with its endpoints at the tongue tip and root to approximate the tongue shape.

Then as shown above, angle A (from the left side of the base line to the end of the velum) and angle B (from the left side of the base line to the beginning of the velum) from each speaker were measured, and the average from the two speakers was taken. [54] Based on the averaged angle, a template was made as below.

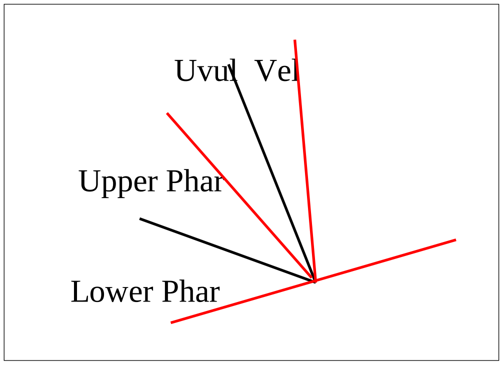


Figure 3.30. Template of place of articulation

The boundary of the velar and uvular areas is drawn at the midpoint of the velar zone (Catford 1988). Also, the boundary of the upper pharyngeal and lower pharyngeal areas is drawn at the midpoint of the pharyngeal area (cf. Gick, Kang, & Whalen 2002). Then the template is applied to the EdgeTraked images.[55] This is shown below.

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[54]

	angle A	angle B
speaker on the left	97.00	55.00
speaker on the right	97.00	51.00
Average	97.00	53.00

[55] There are two columns because the template of /a/ is applied to each /a1/ and /a2/ for the speakers whose /a1/ and /a2/ are significantly different. The maximum constrictions shown in those two columns look slightly different from each other, which reflects the difference between /a1/ and /a2/. One may wonder why one of the vowels should be used. Images of /a/ in Zhu & Hatano from which I created the template were taken from the citation form #a# (between pauses), which does not have the same phonetic condition as our forms /a1/ (beginning of words) and /a2/ (ending of words). In order to create only one column, I could choose /a1/ because /a1/ has an accent just like the citation form #a#, but /a2/ does not. The accent of Japanese is produced with H tone, and for all the speakers showing different /a1/ and /a2/ in my experiment, tongue root of /a1/ is more advanced than /a2/. However, it is not known that the speakers in Zhu & Hatano do the same thing. H toned vowel of those speakers could be produced with retracted tongue root, as Nakajo (1989: 63) introspects that H toned /a/ is retracted. Also Meechan (1992) observes in Khmer speakers the H tone comes with tongue root retraction rather than advancement. These suggest that tongue root and tone could be independent from each other, and the connection between the two could vary across speakers. Because of the uncertain activity of tongue root in relation to tone, I have put both of /a1/ and /a2/ in the Figure 3.31.

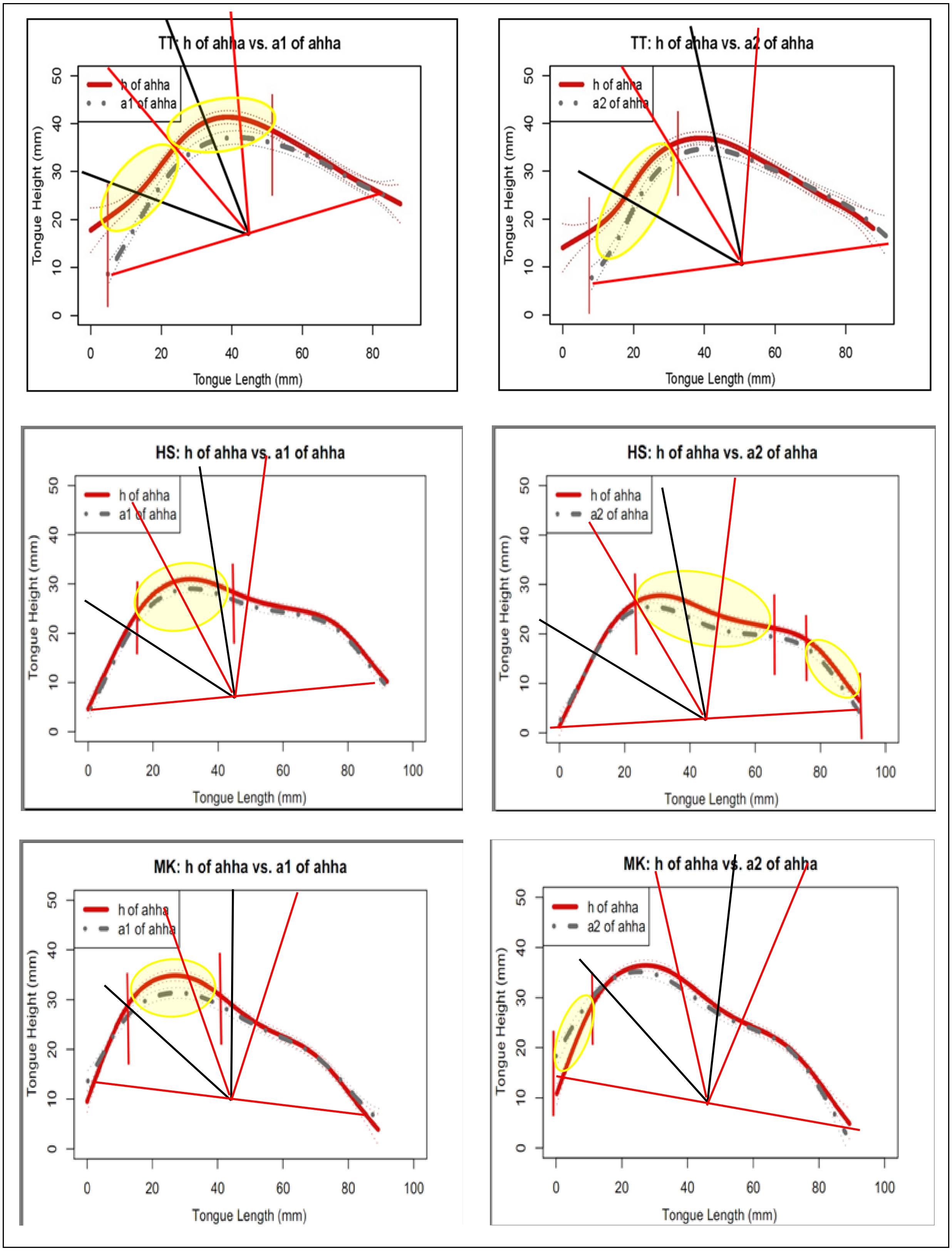

Figure 3.31. Application of the template to /h/: TT, HS, MK

The areas where there is a significant difference between the /h/ contour and the /a/ contour are highlighted with a yellow oval. Based on these markings, the CLs of /h/ relative to each a1 and a2 are summarized below.

(3.7) Constriction location of /h/ relative to a1 and a2: TT, HS, MK

	a1 vs. /h/	/h/ vs. a2
TT	lower pharyngeal, upper pharyngeal, uvular, velar, palatal	lower pharyngeal, upper pharyngeal
HS	upper pharyngeal, uvular	uvular, velar, palatal, alveolar
MK	upper pharyngeal, uvular	(lower pharyngeal)

The /h/s of TT and HS in general have a greater constriction around pharyngeal area relative to both a1 and a2, which categorize them as pharyngeal-type /h/. But this situation does not hold for MK, whose /h/ is not outside of a2 despite the fact that a significant difference is found in the lower pharyngeal area; this is why parentheses are used for 'lower pharyngeal' in the column of /h/ vs. a2 There are some differences, but for all three speakers, constrictions are attested in the uvular and upper pharyngeal areas.

The following SS-ANOVA shows the assimilation-type of /h/, which is for AM and YS. /h/ vs. a2 is omitted here, as they are identical because of assimilation.

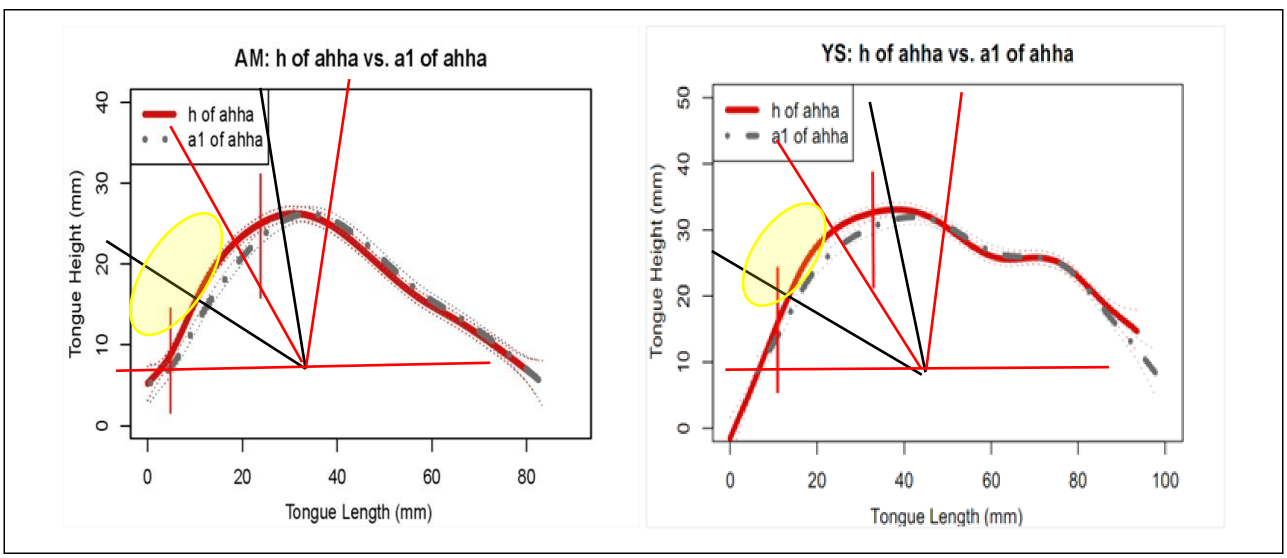

Figure 3.32. Application of the template to /h/: AM, YS

Again, based on the yellow marking showing location, the CLs of /h/ relative to a1 are summarized below.

(3.8) Constriction location of /h/ relative to a1 and a2: AM, YS

	a1 vs. /h/	/h/ vs. a2
AM	lower pharyngeal, upper pharyngeal	N/A
YS	lower pharyngeal, upper pharyngeal	N/A

Recall that assimilation can be interpreted as either dorso-pharyngeal or pharyngeal, depending on which segment is assumed to trigger assimilation. It was shown that under the assumption of a2-as-trigger, /h/ may become dorso-pharyngeal, while under the assumption of /h/-as-trigger, /h/ may be pharyngeal. The template analysis supports the latter, or the hypothesis that /h/ is pharyngeal, because the constriction of AM and YS's /h/ is made at the pharyngeal area. For /h/ to be dorso-pharyngeal, the dorsum as well as the tongue root should have a significant constriction (see Trigo 1991). In the cases of AM and YS, the dorsum raising of /h/ is not significant (see Figure 3.11 for AM and Figure 3.14 for YS).

On the other hand, HS, TT and MK have significant dorsum raising (see Figure 3.12 for HS, Figure 3.13 for TT, Figure 3.16 for MK) and significant tongue root retraction. Again, MK's pharyngeal constriction is only in a1 vs. /h/ and not in /h/ vs. a2, and only in /ahha/ and not in /ihhi/. In this sense MK's evidence for pharyngeal-type /h/ is weaker than that for HS and TT, but I will group MK with TT and HS, who show the same patterning in dorsum raising. Thus the /h/ of this group should be categorized as *dorso-pharyngeal*. According to Trigo (1991), dorso-pharyngeals which use both the dorsum and the pharynx as articulators are one type of uvular.

The preliminary summary of /h/ across subjects (3.6) was suggested in section 3.3.4. Now the revised version will be presented, as the template analysis produced more solid answers. The updated summary is given below, with the old version for comparison.

(3.9) Summary of types of /h/: Template analysis

	preliminary version (3.6)	template analysis
AM	dorso-pharyngeal or pharyngeal	pharyngeal [ħ][56]
HS	pharyngeal	dorso-pharyngeal / uvular [χ]
TT	pharyngeal	dorso-pharyngeal / uvular [χ]
YS	dorso-pharyngeal or pharyngeal	pharyngeal [ħ]
KK	placeless or dorsal	placeless [h] or dorsal [x]
MK	uncategorized	dorso- pharyngeal / uvular [χ]

Pharyngeal-type /h/ in the preliminary version is now categorized as dorso-pharyngeal, which is equivalent to uvular (HS, TT). The former 'assimilation-type' /h/s (AM, YS) are no longer ambiguous, and the current analysis found their PoA is pharyngeal. MK's /h/ was uncategorized in the earlier version, but in the current analysis in which I included dorsum raising as a criterion, it should be dorso-pharyngeal, being grouped with HS and TT, because both dorsum raising and pharyngeal constriction are observed.

I conclude that at least 5 out of 6 Japanese speakers' /h/ is not placeless. A dorso-pharyngeal place is suggested for three speakers, and a pharyngeal place is suggested for two speakers. Thus the traditionally-transcribed [h] in Japanese phonetics may be replaced by [ħ] and [χ].

3.5. Conclusion

In this chapter, multiple case studies were conducted in order to test the hypothesis that /h/ is specified for place. I have argued that Japanese /h/ may be pharyngeal depending on the speaker. I used articulatory evidence to infer the phonological specification, based on the hypothesis of generative phonetics that featural specification/nonspecification has a direct correspondence to phonetic realization. Following the categorical vs. gradient criteria, I showed the three possible featural representations, based on the results of articulatory patterns. If the

[56] This could be a pharyngeal fricative or pharyngeal approximant, but I identified it as a fricative because of the presence of frication acoustically.

contour of /h/ is outside both a1 and a2, it is pharyngeal. This pattern is seen for TT and HS. If the contour of /h/ is somewhere between a1 and a2, meaning the interpolation is gradient, then it should be placeless. This pattern is seen for KK.

The variability of articulatory data and phonological specifications poses some questions: why does /h/ show much articulatory variability among speakers even within the same language? Mielke (2008: 77) states:

> Universal distinctive features are most reliable for predicting the behavior of phonetically unambiguous segments, which suggest that the phonetic unambiguity is responsible for the phonological patterning. In the phonetic gray areas, where universal features would be expected to define clear boundaries between two values of a feature, the phonological patterning of sounds is as varied as the phonetic cues are ambiguous.

This suggests that the hypothesis of universality may explain prototypical segments for the feature better (e.g., stop consonants for [-cont], vowels for [+cont]),[57] but nonprototypical segments for the feature (e.g., nasals and laterals for [cont]) need a different account.

As multiple instantiations of a feature are attested crosslinguistically (Pulleyblank 2006a, b, 2011, among others), it would not be surprising if features concomitant to /h/ have multiple instantiations. /h/ is not a prototypical segment for [+consonantal] (or C-place), thus researchers sometimes dub /h/ as an "approximant" (e.g., Keating 1988), or a "glide" (e.g., SPE, Mudzingwa 2010), or the devoiced counterpart of the following vowel (e.g., Kaneko & Neyer 1984) (and perhaps not prototypical for [-voice] either).

As the phonetic cues are ambiguous in this way, the phonological ambivalence such as having both pharyngeal /h/ and placeless /h/ in a language may be more likely to emerge. In this respect, the findings here may speak in favor of the emergentist position of distinctive features (Pulleyblank 2003a, b, 2006a, b, 2011, Mielke 2008, Kim & Pulleyblank 2009, Mielke, Baker & Archangeli 2010, Archangeli, Baker & Mielke 2011).

The distinction between pharyngeal /h/ and placeless /h/ of Japanese is not audible, at least to my ears.[58] According to Scobbie, Gibbon, Hardcastle and Fletcher (2000), such

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[57] But it also argues that universality is unnecessary in the prototypical cases.

[58] But some Japanese researchers state that before nonhigh vowels, /h/ can be optionally pronounced as a velar fricative (Kawakami 1977) or a uvular fricative (Akamatsu 1997). Since no instrumental data are given, these categorizations seem to be based on their auditory impressions. However, auditory judgment of postvelar segments

ambiguous phonetic cues are often not contrastive to adults' ears but audible in early language acquisition, and this type of contrast may be referred to as *covert contrast*. The finding of individual variation over a single phoneme is not new, but what is interesting is there may be two types of covert contrast. For example, regarding the variations about /r/, Mielke, Baker & Archangeli (2010: 725) state that there are (i) articulatorily different /r/s without creating obvious perceptual differences, as in American /r/, and (ii) /r/s which are "more perceptually and socially salient than in American English", as in Scottish English and Dutch.

The typology of covert contrast awaits further research, but Japanese /h/ is likely to belong to type (i). Thus, I speculate that for this type, individuals may choose the feature in the early stage, and maintain it into the adult grammar.

Although it is challenging to find out the CL without palate tracings, a rough estimate was done with the use of a template. This method found that the /h/ of HS, TT and MK makes constriction around the uvular and upper pharyngeal regions.

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is not so easy, and I wonder whether what they perceive could be pharyngeal. In my auditory impression, TT's /h/ sounds clearer than KK's, though I am not sure if the degree of clarity has any correlation with the degree of specification of features. Trigo (1991) says that the retraction of the tongue root is reflected in the raising of F1 and depressing of F2 and F3, but my acoustic data does not fully support this. Shahin (2002: 34-38) gives predicted acoustic effects of F1 and F2 for pharyngeal and uvular sounds, but the application of the range of Hz needs careful consideration, because it is pointed out that the range of the distribution is not an absolute criterion for categorization of segments (see Pulleyblank 2006a, b).

Chapter 4 **Comparison of Three Consonants of Japanese**

4.1. Introduction

The multiple case studies so far have shown that different segments may vary in the characteristics of place. In Chapter 2, we have seen that /N/ has a target for everybody. In Chapter 3, we have seen that /h/ has interspeaker variation, in that having a place or not depends on the speaker. This suggests that whether or not phonologically "placeless" consonants can be phonetically placeless depends on the segment type in Japanese: /h/ can be phonetically placeless depending on the speaker, but /N/ is unlikely to be phonetically placeless.

/N/'s dorsum raising suggests that /N/ has a target. But what is not known yet is whether the targets of /N/ are less constrained compared to place-specified consonants. This question arose from the point of view of Keating (1988). Keating assumes that different consonants have different ranges of realizations, but the so-called "placeless" segments have a wider range of distribution than others. I will call this **the wider range hypothesis** for placeless consonants.

This hypothesis is supported by the phonetic transparency and contextual variability of the unspecified feature, which Keating showed in the shape of the acoustic formants of /h/ in intervocalic position. The prediction that /h/ has a relatively wider range is also compatible with variable classifications of /h/ that we can find in the literature - /h/ is classified as either a 'glottal fricative', 'glottal glide', 'glottal approximant', or 'voiceless vowel'. Since this suggests both manner and PoA of /h/ are variable, both CD and CL are expected to have a wider range.

But when it comes to /N/, our experimental results and the previous literature conflict: The experimental results show that it has a constriction target, which suggests the range should be narrow, while the literature shows it is contextually variable, which suggests the range should be wide. Moreover, even if the constriction degree (y-axis) has a narrow range, the constriction location (x-axis) could have a wide range. This question is closely related to where the target of /N/ is, because the narrower the range is, the more clearly the target should be defined. Thus in this chapter we ask where the target of /N/ is in the dimension of CD and CL, and how it is different relative to the targets of /h/ and /k/. It is predicted that if /N/ is velar, its distribution should completely overlap with that of /k/, but if it is glottal, it should not only overlap with /k/ but also be more largely distributed than /k/.

The wider range hypothesis can be explored in terms of variability i) within context and ii) across contexts, because the concept of variability is loosely defined and there are two different versions of the hypothesis. Keating's version says that a placeless segment is *contextually* determined, so the place of articulation of /h/ in multiple contexts (e.g., /iha/ and /aha/) should have a wider range than that of a place-specified segment (e.g., /b/) in the same multiple contexts (e.g., /iba/ and /aba/). On the other hand, Cohn (1990: 142), who followed Keating's version of the hypothesis and observed nasal flow data of English vs. French and Sundanese, conjectures that the wider range hypothesis might be true to the variability within context, which means "a difference in the realization of different tokens of the *same form*" (Cohn 1990: 149) (emphasis N.Y.). Thus the distribution of /h/ in one context (e.g., /aha/) could have a wider range than that of a place-specified segment (e.g., /k/) in the same context (e.g., /aka/). Both versions of the wider range hypothesis are tested in this chapter.

This chapter is organized as follows: sec. 4.2. shows methodology and sec. 4.3. shows the results of the experiments: sec. 4.3.1. presents results of the targets of /h, N, k/ *within the mono-context* of /aCa/, and sec. 4.3.2. presents results of the targets of those segments in the *mixed-contexts* of /aCa/ and /iCi/. Sec 4.4. concludes the chapter.

4.2. Methodology

Multiple case studies were conducted to examine whether the range of CD and CL of /N/ is wider than /h/ or /k/.

4.2.1. Subjects

Subjects are the same as in sec. 2.2.1.

4.2.2. Stimuli

Three segments /N, h, k/ are compared in two kinds of contexts, (i) mono-context and (ii) mixed-contexts, and the target words for each context are given below:

(4.1) Target words for each context

(i) Mono-context: /aNa/ vs. /ahha/ vs. /akka/

(ii) Mixed-context: /aNa, iNi/ vs. /ahha, ihhi/ vs. /akka, ikki/

The primary purpose of the comparison of the three segments is to try to find targets of /N/. The general idea is to find whether /N/ is similar to a placeless segment such as /h/, or to a place-specified segment. /k/ was selected as a baseline for the place-specified consonant, because its PoA and manner are least controversial among the Japanese stop consonants /p, t, k/. /p/'s PoA is labial, with no bearing on the place on the tongue, so it cannot be set as a baseline. /t/'s PoA is alveolar, but before /i/ it is palatalized to [ʧ], where the PoA shifts backward to palato-alveolar. In contrast, /k/'s PoA is velar, which is uncontroversial in Japanese linguistics.

For the mixed context of /aCa/ and /iCi/, /i/ and /a/ were selected, because these vowels have opposite values in both height and backness.

The /a/ context was chosen as the mono-context, because among the Japanese vowels /a, i, u, e, o/, /a/ makes the consonant constriction stand out most conspicuously. This makes sense as /a/ lowers the tongue all the way to the bottom of the mouth, while consonants raise the tongue to make constrictions. In contrast, /i/ raises the tongue highest among the Japanese vowels, so the CD that consonants make is somewhat closer to /i/, which obscures the difference between /h, N, k/ (see Figure B. 1. in Appendix). Since the first part of this chapter aims to compare the consonantal constriction and location among /h, N, k/, and the variability within tokens, I decided to use the /a/ context mainly.

The entire list of stimuli that subjects read is in Tables A. 1. - A. 4. in Appendix.

4.2.3. Procedures

Data-gathering procedures followed those described in section 2.2.3.

4.2.4. Analysis

Most analyses are the same as in sec. 2.2.4. except for the following.

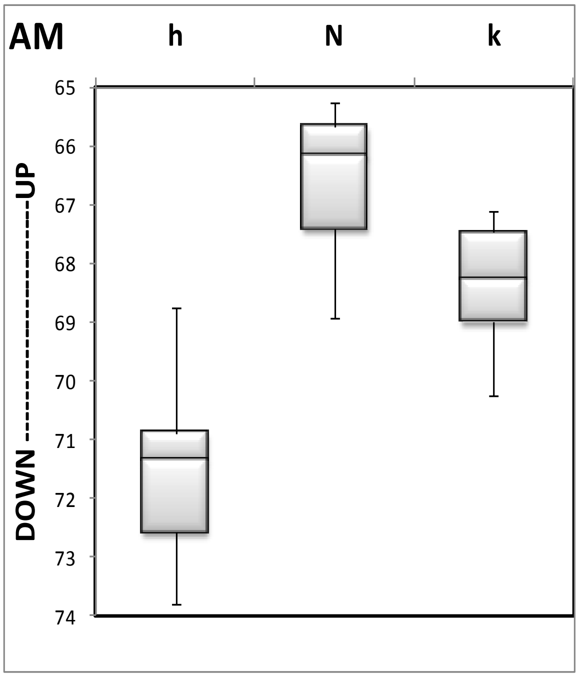
Since the dorsal constriction is stronger in /k/ than /N/, and that in /N/ is stronger than in /h/, it is expected that the difference of the tongue contours between the /a/ context and the /i/ context is the largest in /h/, and the smallest in /k/. This general tendency is observed in Figure B. 8. - Figure B. 13. in Appendix, where SS-ANOVA graphs were generated for /a<u>hh</u>a/ vs. /i<u>hh</u>i/, /a<u>N</u>a/ vs. /i<u>N</u>i/, and /a<u>kk</u>a/ vs. /i<u>kk</u>i/. The values of CL (x-axis) and CD (y-axis) of the peak of the tongue were extracted at the temporal midpoint for all tokens of /h, N, k/. Then the data of x-values and y-values were separated, and boxplots were created for both the mono-context and the mixed-context. Standard Deviation, IQR and F-test were used to explore the variability. The P-values were shaded in green if significant by the normal method, and in gray if not significant by the Holm-Bonferroni method (see sec. 3.2.4. for examples).

4.3. Results of Targets within /a/ Context

4.3.1. Constriction Degree

The graphs below show the CD of peak of the tongue for each a1 (the first [a]), C, and a2 (the second [a]) in /aCa/, where the Cs are /h/, /N/ and /k/ in comparison.

The general result is that the widest range of CD is found in /N/ for three speakers, but in /h/ or /k/ in other speakers. For all speakers, t-tests found a significant difference in every pair between /h/ vs. /N/ vs. /k/, suggesting that each segment has a different target in CD. Across speakers, the tongue body is lowest in /h/. The highest tongue body is in /k/ for five speakers, and in /N/ for only AM. (The general difference of peak CD target among /a<u>hh</u>a, a<u>N</u>a, a<u>kk</u>a/ is also confirmed in Figure B. 2. - Figure B. 7. in Appendix).

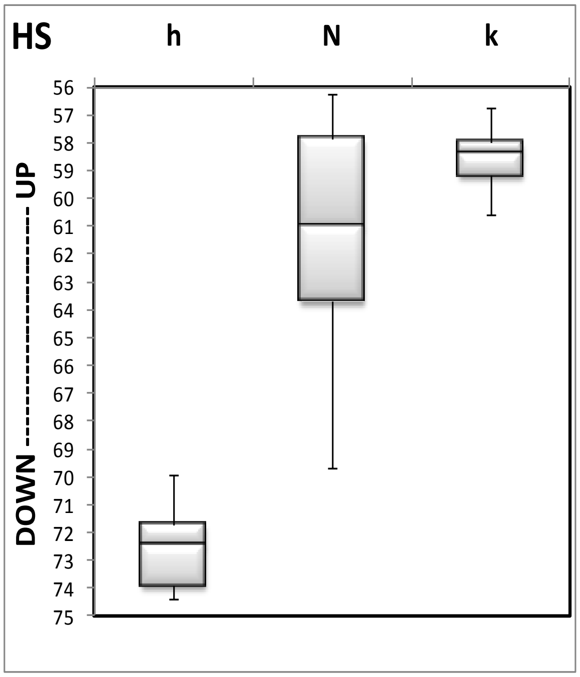


Labels	h	N	k
Mean	71.57	66.59	68.33
SD	**1.33**	1.30	1.02
Min	68.74	65.26	67.12
Q_1	70.8825	65.6575	67.47
Median	71.355	66.17	68.26
Q_3	72.5725	67.3975	68.9775
Max	73.79	68.93	70.25
IQR	1.69	**1.74**	1.5075

AM-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	$p < 0.005$

Figure 4.1. Boxplots of constriction degree: AM: *ahha*, *aNa*, *akka*

In AM's speech, the largest IQR is found in /N/, but the largest SD is in /h/. Unlike the rest of the speakers, AM's /N/ is higher than /k/, rather than the reverse. According to the mean values, /N/ is higher than /h/ by 4.98 mm, and /N/ is higher than /k/ by 1.74 mm. T-tests found a significant difference between every pair of /h/ vs. /N/, /h/ vs. /k/, and /N/ vs. /k/.

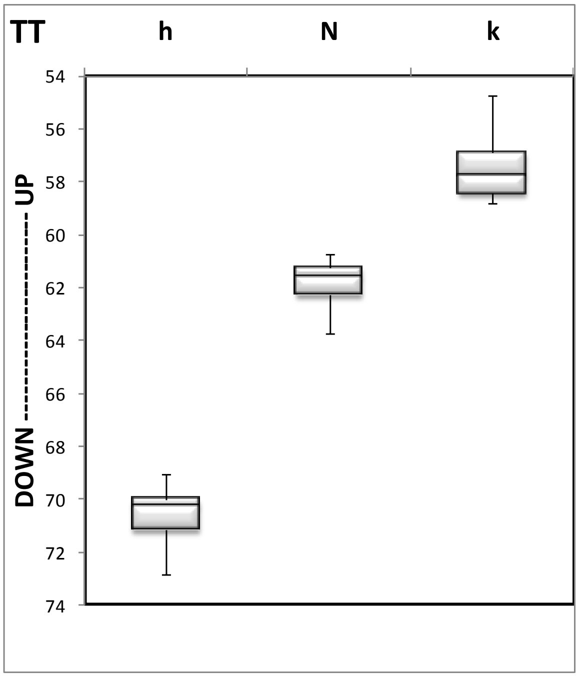


Labels	h	N	k
Mean	72.58	61.54	58.52
SD	1.48	**4.40**	1.19
Min	69.91	56.27	56.72
Q_1	71.705	57.85	57.985
Median	72.47	61	58.375
Q_3	73.8825	63.65	59.18
Max	74.38	69.65	60.59
IQR	2.1775	**5.8**	1.195

HS-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	$p < 0.05$

Figure 4.2. Boxplots of constriction degree: HS: *ahha*, *aNa*, *akka*

In HS's speech, unlike the rest of the speakers, IQR and SD of /N/ is much larger than those of /h/ or /k/, suggesting that HS's /N/ has relatively higher variability in CD. The mean difference between /h/ and /k/ is 14.16 mm, and /k/ is higher than /N/ by 3.02 mm. T-tests found a significant difference between every pair of /h/ vs. /N/, /h/ vs. /k/, and /N/ vs. /k/.

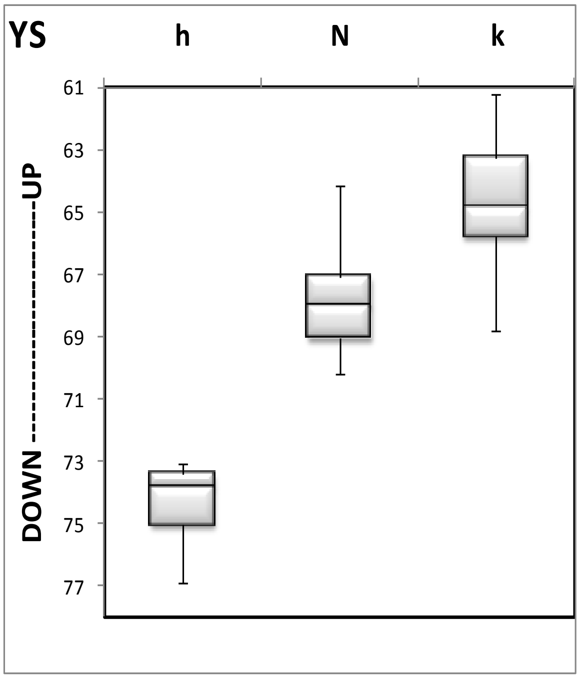


Labels	h	N	k
Mean	70.62	61.94	57.54
SD	1.17	**1.25**	1.19
Min	69.08	60.72	54.72
Q_1	69.9875	61.2575	56.9
Median	70.265	61.6	57.75
Q_3	71.125	62.25	58.42
Max	73.21	65.43	58.79
IQR	1.1375	0.9925	**1.52**

TT-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	$p < 0.001$

Figure 4.3. Boxplots of constriction degree: TT: *ahha*, *aNa*, *akka*

In TT's speech, the largest IQR is found in /k/, but the largest SD is in /N/. The mean difference between /h/ and /k/ is 13.08 mm, and /k/ is higher than /N/ by 4.40 mm. /k/ has the largest IQR but /N/ has the largest SD. T-tests found a significant difference between every pair of /h/ vs. /N/, /h/ vs. /k/, and /N/ vs. /k/.

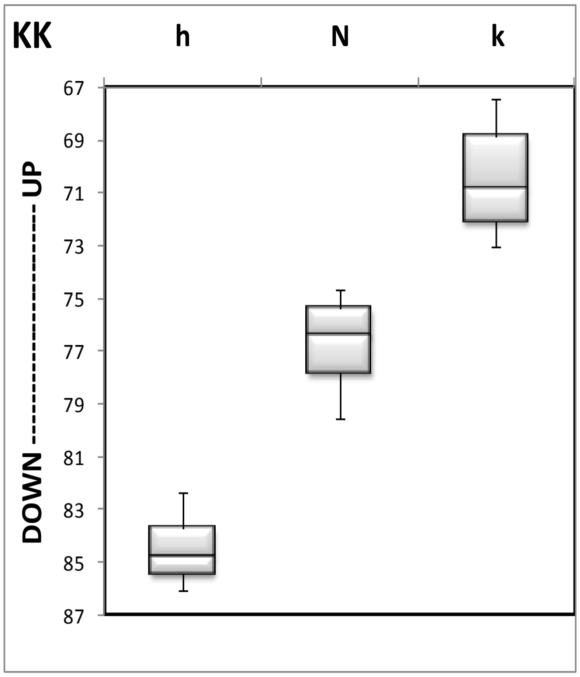


Labels	h	N	k
Average	74.31	67.66	64.83
SD	1.19	2.05	**2.07**
Min	73.07	63.74	61.24
Q_1	73.4125	67.0675	63.2725
Median	73.82	67.995	64.875
Q_3	75.0275	69.01	65.78
Max	76.92	70.21	68.78
IQR	1.615	1.9425	**2.5075**

YS-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	$p < 0.001$

Figure 4.4. Boxplots of constriction degree: YS: *ahha*, *aNa*, *akka*

In YS's speech, /k/ has the largest IQR and SD. The mean difference between /h/ and /k/ is 9.48 mm, and /k/ is higher than /N/ by 2.83 mm. T-tests found a significant difference between every pair of /h/ vs. /N/, /h/ vs. /k/, and /N/ vs. /k/.

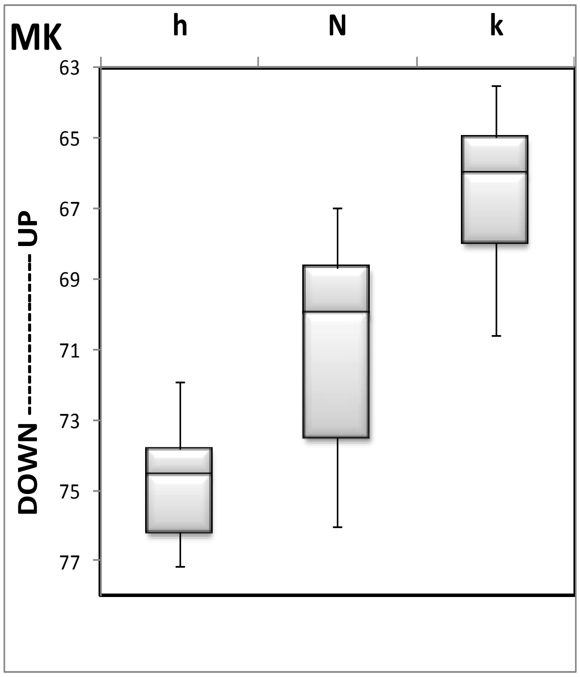


Labels	h	N	k
Mean	84.57	76.57	70.46
SD	1.08	1.59	**1.85**
Min	82.33	74.69	67.45
Q_1	83.72	75.3775	68.86
Median	84.805	76.385	70.885
Q_3	85.4325	77.805	72.0875
Max	86.04	79.53	73.03
IQR	1.7125	2.4275	**3.2275**

KK-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	$p < 0.001$

Figure 4.5. Boxplots of constriction degree: KK: *ahha, aNa, akka*

In KK's speech, /k/ has the largest IQR and SD. The mean difference between /h/ and /k/ is 14.11 mm, and /k/ is higher than /N/ by 6.11 mm. T-tests found a significant difference between every pair of /h/ vs. /N/, /h/ vs. /k/, and /N/ vs. /k/.



Labels	h	N	k
Mean	74.92	70.88	66.52
SD	1.63	**2.95**	2.29
Min	71.93	66.98	63.5
Q_1	73.845	68.68	64.9825
Median	74.575	69.985	66.03
Q_3	76.1625	73.48	67.975
Max	77.17	76	70.6
IQR	2.3175	**4.8**	2.9925

MK-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	$p < 0.001$

Figure 4.6. Boxplots of constriction degree: MK: *ahha*, *aNa*, *akka*

In MK's speech, /N/ has the largest IQR and SD. The mean difference between /h/ and /k/ is 8.4 mm, and /k/ is higher than /N/ by 4.36 mm. T-tests found a significant difference between every pair of /h/ vs. /N/, /h/ vs. /k/, and /N/ vs. /k/.

To summarize, the major tendency is that /k/ has the highest CD (i.e., highest dorsum), /h/ has the lowest CD (i.e., lowest dorsum), and /N/ is in between. Only AM (see Figure 4.1) diverges from this tendency: /N/ rather than /k/ has the highest CD. The difference in the CD among /N/ vs. /k/, /N/ vs. /h/ and /h/ vs. /k/ is confirmed using t-tests, as summarized in Table 4.1.

Table 4.1. T-test results (unpaired) for *ahha*, *aNa*, and *akka*

CD /a/	AM	HS	TT	YS	KK	MK
N vs. h	<.001	<.001	<.001	<.001	<.001	<.001
N vs. k	<.01	<.05	<.001	<.001	<.001	<.001
h vs. k	<.001	<.001	<.001	<.001	<.001	<.001

For all speakers, the significant difference was confirmed.

To determine the variability of peak CD, SD and IQR were calculated. Both measures suggest that the ranking of SD from largest to smallest is /N/ > /k/ > /h/ (> means 'larger than') on average for the 6 speakers. Table 4.2. shows SD of /h, N, k/ for each speaker, and the average of the 6 speakers.

Table 4.2. Standard deviations of constriction degree for *ahha*, *aNa*, and *akka*

CD /a/	AM	HS	TT	YS	MK	KK	AVG
h SD	**1.33**	1.48	1.17	1.19	1.63	1.08	1.31
N SD	1.30	**4.40**	**1.25**	2.05	**2.95**	1.59	**2.26**
k SD	1.02	1.19	1.19	**2.07**	2.29	**1.85**	1.60

The ranking is not uniform across speakers. /N/ > /k/ > /h/ holds for TT and MK only. For AM, it is /h/ ≈ /N/ > /k/ (1.33 vs. 1.30 is hardly meaningful, assuming that there is always some measurement error), /N/ > /h/ > /k/ for HS, /N/ ≈ /k/ > /h/ for YS, and /k/ > /N/ > /h/ for KK. Based on these observations, we can see that any of the three segments can have the highest SD depending on the speaker.

IQR is presented below as another measure of variability. The result here in general is parallel to the result of SD: The average ranking of IQR from largest to smallest is /N/ > /k/ > /h/.

Table 4.3. IQR of constriction degree for *a<u>hh</u>a*, *a<u>N</u>a*, and *a<u>kk</u>a*

CD /a/	AM	HS	TT	YS	MK	KK	AVG
h IQR	1.69	2.18	1.14	1.62	2.32	1.71	1.78
N IQR	**1.74**	**5.80**	0.99	1.94	**4.80**	2.43	**2.95**
k IQR	1.51	1.20	**1.52**	**2.51**	2.99	**3.23**	2.16

But here again, the ranking is not uniform across speakers. The ranking /N/ > /k/ > /h/ holds for only MK. The ranking is /N/ > /h/ > /k/ for AM and HS, /k/ > /N/ > /h/ for YS and KK, and /k/ > /h/ > /N/ for TT.

In both SD and IQR, HS conspicuously raises the overall average of /N/. This suggests that HS's /N/ has higher variability compared to other speakers, which can be visually confirmed in HS's boxplots in Figure 4.2.

The result of F-tests below also shows that HS's variance of /N/ was significantly different from that of /h/ and /k/.

Table 4.4. F-tests of variance for *a<u>hh</u>a*, *a<u>N</u>a*, and *a<u>kk</u>a* (P-values)

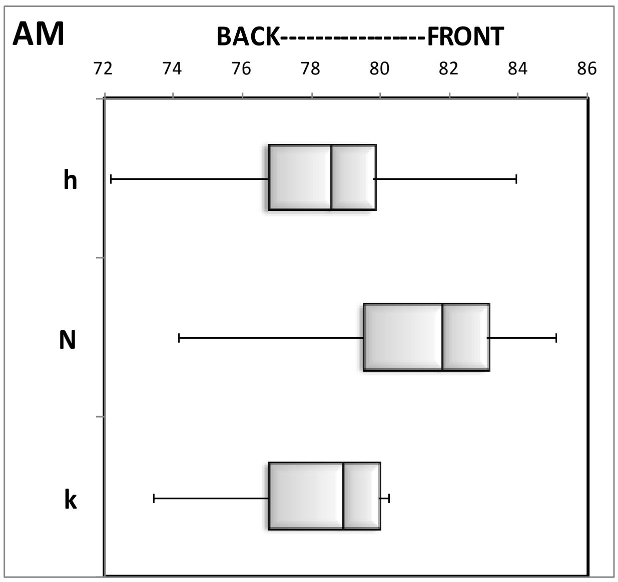
CD /a/	h vs. N	N vs. k	h vs. k
AM	0.937	0.432	0.388
HS	<.001	<.001	0.470
TT	0.841	0.880	0.960
YS	0.085	0.986	0.082
MK	0.060	0.415	0.271
KK	0.218	0.618	0.088

HS's higher variability may be taken as an individual articulatory characteristic, or a kind of hyper-articulation caused by reading the word list. Nonetheless, the overall tendency is that none of /h/, /N/ and /k/ shows significantly higher variability than any of the others.

4.3.2. Constriction Location

4.3.2.1. Comparing Tongue Peaks of Three Segments

The graphs below show the CL of peak of the tongue for each a1 (the first [a]), C , and a2 (the second [a]) in /aCa/, where the Cs are /h/, /N/ and /k/ in comparison. The results show that the location of /N/ relative to /h/ and /k/ is different across speakers.

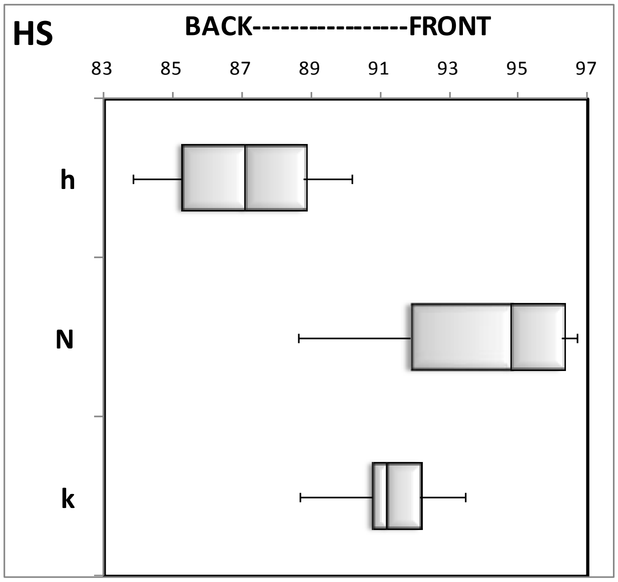


Labels	h	N	k
Mean	78.34	81.16	78.17
SD	3.02	**3.2**	2.22
Min	71.44	73.71	73.43
Q_1	76.7625	79.5225	76.785
Median	78.6	81.795	78.92
Q_3	79.805	83.0975	79.9525
Max	83.94	85.11	80.26
IQR	3.0425	**3.575**	3.1675

AM-x P-value (t-test)	
h vs. N	$p < 0.05$
h vs. k	0.11962571
N vs. k	$p < 0.05$

Figure 4.7. Boxplots of constriction location: AM: *a<u>hh</u>a*, *a<u>N</u>a*, *a<u>kk</u>a*

In AM's speech, /N/ has the highest IQR and SD. T-tests found a significant difference between /h/ vs. /N/ and /N/ vs. /k/, but not between /h/ vs. /k/. The location of /N/ is farther forward compared to /h/ and /k/. The mean difference between /h/ and /N/ is 8.4 mm, and /N/ is farther forward than /k/ by 2.99 mm.

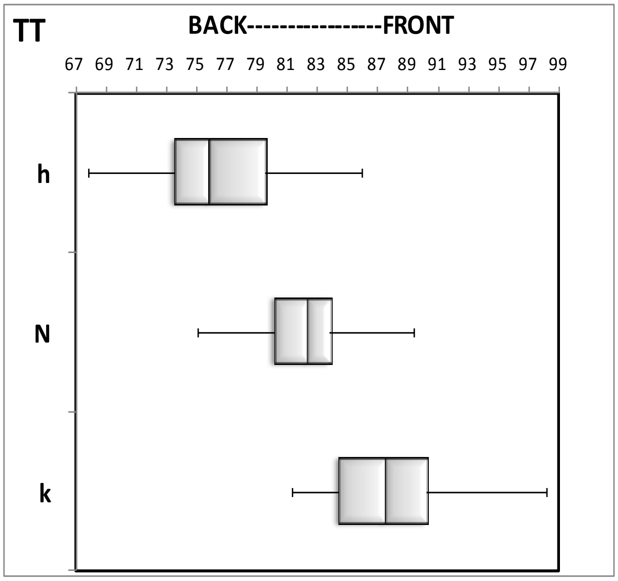


Labels	h	N	k
Mean	87.18	93.82	91.08
SD	2.12	**2.84**	1.67
Min	83.88	88.65	87.59
Q_1	85.2725	91.915	90.7875
Median	87.1	94.79	91.205
Q_3	88.82	96.2975	92.165
Max	90.23	96.72	93.49
IQR	3.5475	**4.3825**	1.3775

HS-x P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.05$
N vs. k	$p < 0.01$

Figure 4.8. Boxplots of constriction location: HS: *ahha*, *aNa*, *akka*

In HS's speech, /N/ has the largest IQR and SD. Like AM's, the location of /N/ is farther forward compared to /h/ and /k/. But /h/ is the farthest back. There is a significant difference between every pair among the three segments. The mean difference between /h/ and /N/ is 6.64 mm, and /N/ is farther forward than /k/ by 2.74 mm.

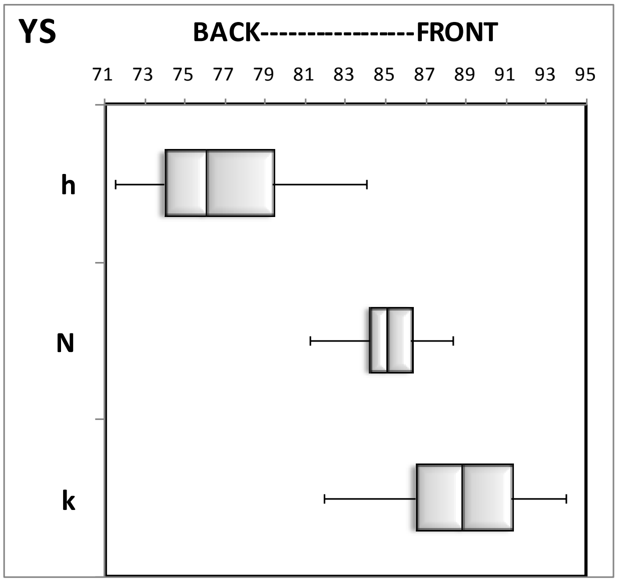


Labels	h	N	k
Mean	76.86	82.77	88.09
SD	5.04	4.53	**5.16**
Min	67.91	75.18	81.44
Q_1	73.615	80.2	84.4625
Median	75.885	82.4	87.485
Q_3	79.5525	83.885	90.2275
Max	86.03	94.02	98.22
IQR	**5.9375**	3.685	5.765

TT-x P-value (t-test)	
h vs. N	$p < 0.005$
h vs. k	$p < 0.005$
N vs. k	$p < 0.001$

Figure 4.9. Boxplots of constriction location: TT: *ahha, aNa, akka*

In TT's speech, /h/ has the largest IQR but /k/ has the largest SD. T-tests found a significant difference between every pair among the three segments. Unlike AM's and HS's, the location of /k/ is farther forward compared to /h/ and /k/. But like HS's, /h/ is the farthest back. The mean difference between /h/ and /k/ is 11.23 mm, and /N/ is farther back than /k/ by 5.32 mm.

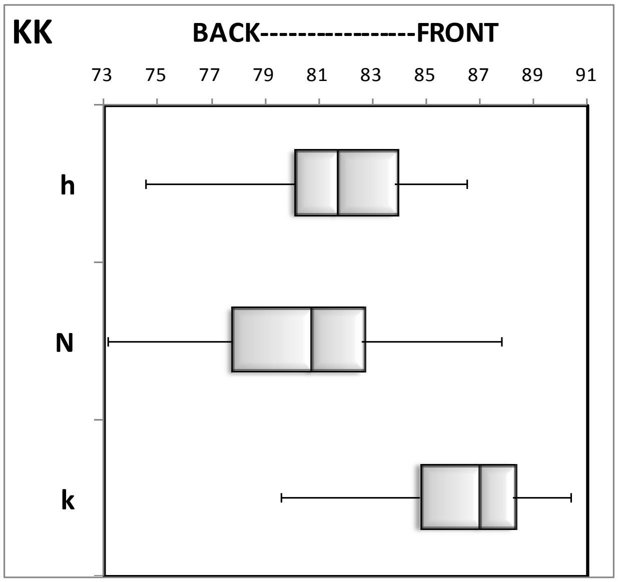


Labels	h	N	k
Mean	76.64	85.06	88.49
SD	**3.9**	2.2	3.76
Min	71.59	79.64	82.01
Q_1	74.03	84.26	86.54
Median	76.08	85.07	88.85
Q_3	79.3775	86.2575	91.2775
Max	84.13	88.41	94.02
IQR	**5.3475**	1.9975	4.7375

YS-x P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p <0.0001$
N vs. k	$p < 0.05$

Figure 4.10. Boxplots of constriction location: YS: *ahha*, *aNa*, *akka*

In YS's speech, /h/ has the largest IQR and SD. T-tests found a significant difference between every pair among the three segments. Like TT's, the location of /k/ is farther forward compared to /h/ and /k/. But like HS's, /h/ is the farthest back. The mean difference between /h/ and /k/ is 11.85 mm, and /N/ is farther back than /k/ by 3.43 mm.

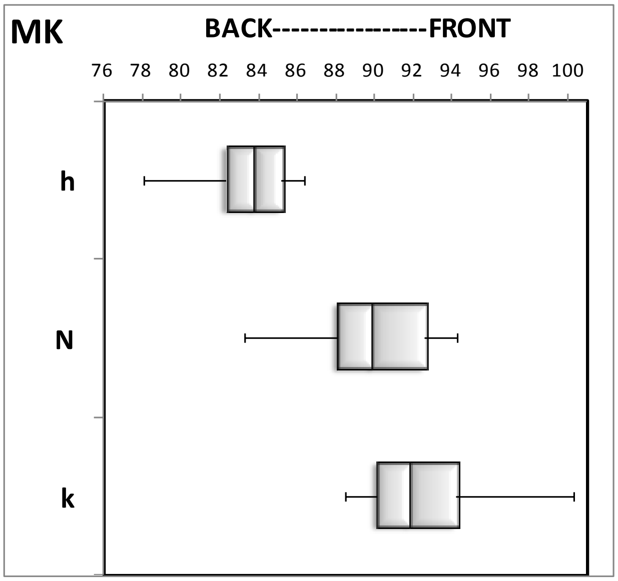


Labels	h	N	k
Mean	81.59	80.87	86.16
SD	3.45	**4.12**	3.45
Min	74.6	73.17	78.9
Q_1	80.15	77.825	84.82
Median	81.715	80.74	87.025
Q_3	83.855	82.6325	88.29
Max	86.57	87.88	90.46
IQR	3.705	**4.8075**	3.47

KK-x P-value (t-test)	
h vs. N	0.68905518
h vs. k	0.1893437
N vs. k	$p < 0.005$

Figure 4.11. Boxplots of constriction location: KK: *ahha*, *aNa*, *akka*

In KK's speech, /N/ has the largest IQR and SD. T-tests found a significant difference between /N/ and /k/ only. Like YS's and TT's, the location of /k/ is the farthest forward. /h/ and /N/ are not significantly different, suggesting that they have a similar location target. Both of these are farther back than /k/. The mean suggests that /N/ is farther back than /k/ by 5.29 mm.



Labels	h	N	k
Mean	83.38	89.78	92.56
SD	2.64	3.38	**3.39**
Min	76.78	83.34	88.54
Q_1	82.385	88.1125	90.17
Median	83.845	89.92	91.835
Q_3	85.2225	92.645	94.2525
Max	86.42	94.38	100.4
IQR	2.8375	**4.5325**	4.0825

MK-x P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	0.05224648

Figure 4.12. Boxplots of constriction location: MK: *ahha, aNa, akka*

In MK's speech, /N/ has the largest IQR but /k/ has the largest SD. T-tests found a significant difference between /h/ vs. /N/ and /h/ vs. /k/, but not in /N/ vs. /k/, suggesting that /N/ and /k/ have a similar location target. The location of /N/ and /k/ is farther forward than /h/. The mean suggests that /k/ is farther forward than /h/ by 9.18 mm, and /N/ is farther forward than /h/ by 6.4 mm.

The location of /N/ vs. /k/ or /h/ is confirmed using t-tests, as summarized in Table 4.5.

Table 4.5. T-test results (unpaired) for *ahha*, *aNa*, and *akka* (P-values)

CL	AM	HS	TT	YS	KK	MK
N vs. h	<.01	<.001	<.01	<.001	0.689	<.001
h vs. k	0.120	<.05	<.01	<.0001	0.189	<.001
N vs. k	<.01	<.01	<.001	<.05	<.01	0.052

Interestingly, some of the pairs are not significantly different – /h/ vs. /k/ for AM, /N/ vs. /h/ and /h/ vs. /k/ for KK and /N/ vs. /k/ for MK. The rest of the pairs are significantly different.

These t-test results and the relative position of /N/ among the three segments can tell us i) whether /N/ is distinctively dispersed from the rest or identical with other segments, ii) where /N/ is located compared to /h/ and /k/. Surprisingly, not only the dispersion of /N/, but the relative position of /N/ varies across speakers, ranging from being significantly anterior to /k/ to posterior to /k/, which could be identical to /h/. This is illustrated in Table 4.6.

Table 4.6. Peak location of /N/ relative to /h, k/

	Relative location of /N/	Participants
a.	h (> or ,) k > **N**	AM, HS
b.	h > {**N**, k}	MK[59]
c.	h (> or ,) **N** > k	TT, YS, KK

The variation can be divided into three types: (a) /N/ as pre-/k/, where /N/ is more front than /h/ or /k/ (AM, for whom /h/ and /k/ are not significantly different, and HS, for whom /h/ is more back than /k/); (b) /N/ and /k/ are not significantly different (MK); and (c) /N/ as post-/k/, where /N/ is between /h/ and /k/ (TT, YS), or is not significantly different from /h/ (KK).

Although the well-established assumption is that /k/ is velar, this does not necessarily imply that pre-/k/ is palatal, and post-/k/ is uvular and so on, because /k/ seems to shift around

[59] MK's difference between /N/ vs. /k/ is suggestive (at p = 0.052), therefore MK can perhaps be categorized as group c) N as post-/k/.

/N/ among speakers. Thus it is worth checking where the maximum constriction of /k/ is. This can be done by using an oral tract template, and the result will be shown in the next section.

Another problem is that the separation of the x/y axis in this analysis makes it difficult to grasp a visual image about the actual position of /N/ relative to /h/ and /k/ in the oral cavity. Also it does not give us detailed information about the tongue shape. A more elaborate analysis will be shown in the next section, but here, I provide overlays of the average tracings of tongue shapes. The red solid line indicates /N/, blue dotted line indicates /h/, and green broken line indicates /k/. The highest point of each line is indicated with a dot.

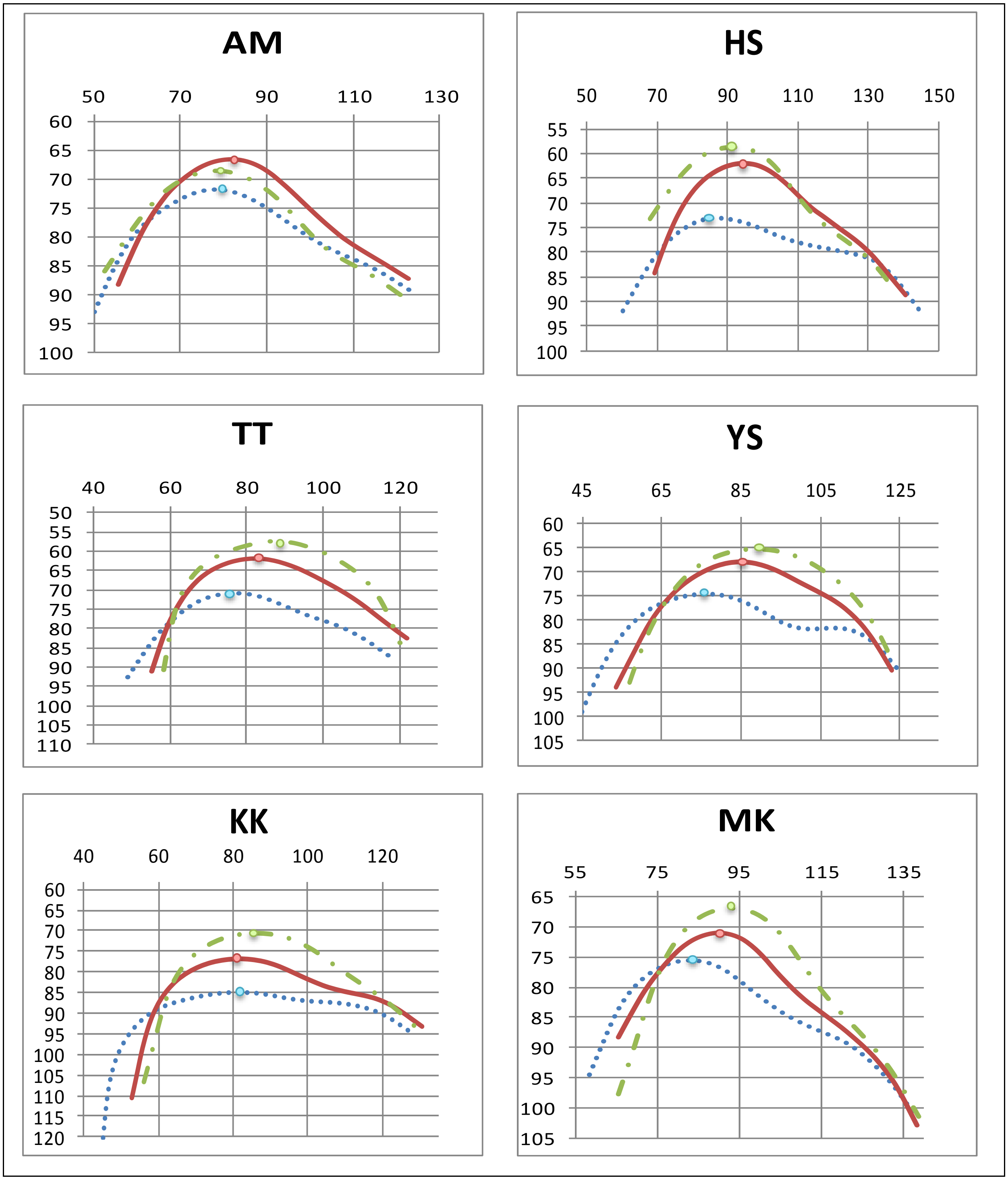


Figure 4.13. Highest point of /h, N, k/ in average tracings: All speakers

Recall, however, that the highest constriction points do not correspond to the height of the tongue body but may show the uvularity, because the actual tongue posture should be obtained with the leftward rotation of the graphs. And of course, the average tracing does not inform us as to anything about variability.

For a measure of variability of the x values at peak constriction locations, (i) Standard Deviation (SD), (ii) IQR and (iii) F-test were used. The results show that no evidence strongly supports the wider range hypothesis for /N/.

The Standard Deviation (SD) for /h, N, k/ is listed below.

Table 4.7. Standard deviations of constriction location for *ahha*, *aNa*, and *akka*

Loc (a)	AM	HS	TT	YS	MK	KK	AVG
h SD	3.02	2.12	5.04	**3.9**	2.64	3.45	3.36
N SD	**3.2**	**2.84**	4.53	2.2	3.38	**4.12**	**3.38**
k SD	2.22	1.67	**5.16**	3.76	**3.39**	3.45	3.28

The segment with the highest SD depends on the speaker. /N/ is highest for AM, HS, and KK, /h/ is highest for TT and YS, and /k/ is highest for MK. As Table 4.7. shows, SD of /N/ was, on average, slightly higher than /h/ or /k/.

IQR of x values at peak CL was also compared as below.

Table 4.8. IQR of constriction location for *ahha*, *aNa*, and *akka*

Loc (a)	AM	HS	TT	YS	MK	KK	AVG
h IQR	3.04	3.55	**5.94**	**5.35**	2.84	3.71	**4.07**
N IQR	**3.57**	**4.38**	3.69	2.00	**4.53**	**4.81**	3.83
k IQR	3.17	1.38	5.76	4.74	4.08	3.47	3.77

The IQR ranking within a talker is parallel with the ranking of SD, except MK. For MK, IQR marks /N/ as the highest while SD marks /k/ as the highest, though /h/ is the lowest in both variability measures. Looking at the average of SD and IQR, we can find that the ranking of highest variability is not the same: SD marks /N/ > /h/ > /k/, while IQR marks /h/ > /N/ > /k/.

For the variance of /N/, F-tests were made as below.

Table 4.9. F-tests of variance for *a<u>hh</u>a*, *a<u>N</u>a*, and *a<u>kk</u>a* (P-values)

CL (a)	h vs. N	N vs. k	h vs. k
AM	0.855	0.245	0.324
HS	0.345	0.094	0.450
TT	0.728	0.673	0.940
YS	0.070	0.088	0.911
MK	0.425	0.996	0.422
KK	0.565	0.567	0.997

The results of F-tests in Table 4.9. also show that the variance of /N/ was comparable to that of /k/ for all speakers.

I conclude that no evidence strongly suggests that the distribution of x-values – i.e., CL - of /N/ is significantly wider than that of /h/ or /k/.

4.3 2.2. Template Analysis

This section tries to find the place of /N/ by using a palate template. In the previous section, variability of the place of /N/ across speakers was detected, but the methodology of comparison of the three segments only allows us to guess the place of /N/ relative to /h/ and /k/. Overall, /h/ is the furthest back among /h, N, k/ for all speakers, but the relative position of /N/ and /k/ seems to be variable across speakers. For this reason, the place of /k/ as well as /N/ need to be checked for each speaker.

In order to find the places for those segments, I will use a template just as I did in sec. 3.4.3. The first thing I will do is to try to elaborate the template, because so far the area before the velum is just one block, and it is not known which zone is palatal and which zone is alveolar. But the zone division is not an easy task, because the boundary between alveolar and palatal is physically continuous, and the end of the alveolar ridge is not clear (see Figure 3.29. for MRI photos). Unless the boundary of zones is specified in the template, we would only be able to make a guess for each photograph of the tongue, which may eventually cause inconsistency in my judgments of constriction location.

In order to avoid such a potential problem, I follow Catford (1988), who specifies the boundary between palatal and alveolar at the midpoint of the length from the front teeth to the beginning of the velum. In our template, the front teeth approximately corresponds to the right edge of the bottom line, and the velum is located at approximately 83 degrees from the bottom line. So the boundary between palatal and alveolar is manually drawn around 41.5 degrees.[60] Each of the palatal and alveolar zones is divided in half as shown with broken lines below. Thus, the alveolar zone has subzones of alveolar and postalveolar, and the palatal zone has subzones of prepalatal and palatal. This is shown below.

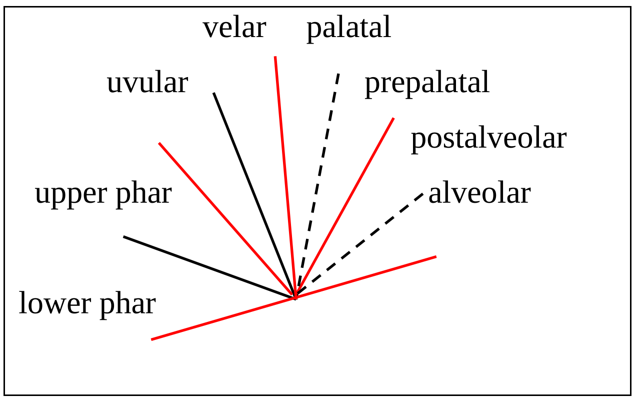


Figure 4.14. Elaborated template of place of articulation

The following shows the outcomes of the application of the template above. The template was applied to a1 vs. /N/ and /N/ vs. a2. Significantly different areas are marked in yellow.

[60] But presumably the regions would vary considerably among individuals, and may be somewhat different for Asian participants (see also fn 45).

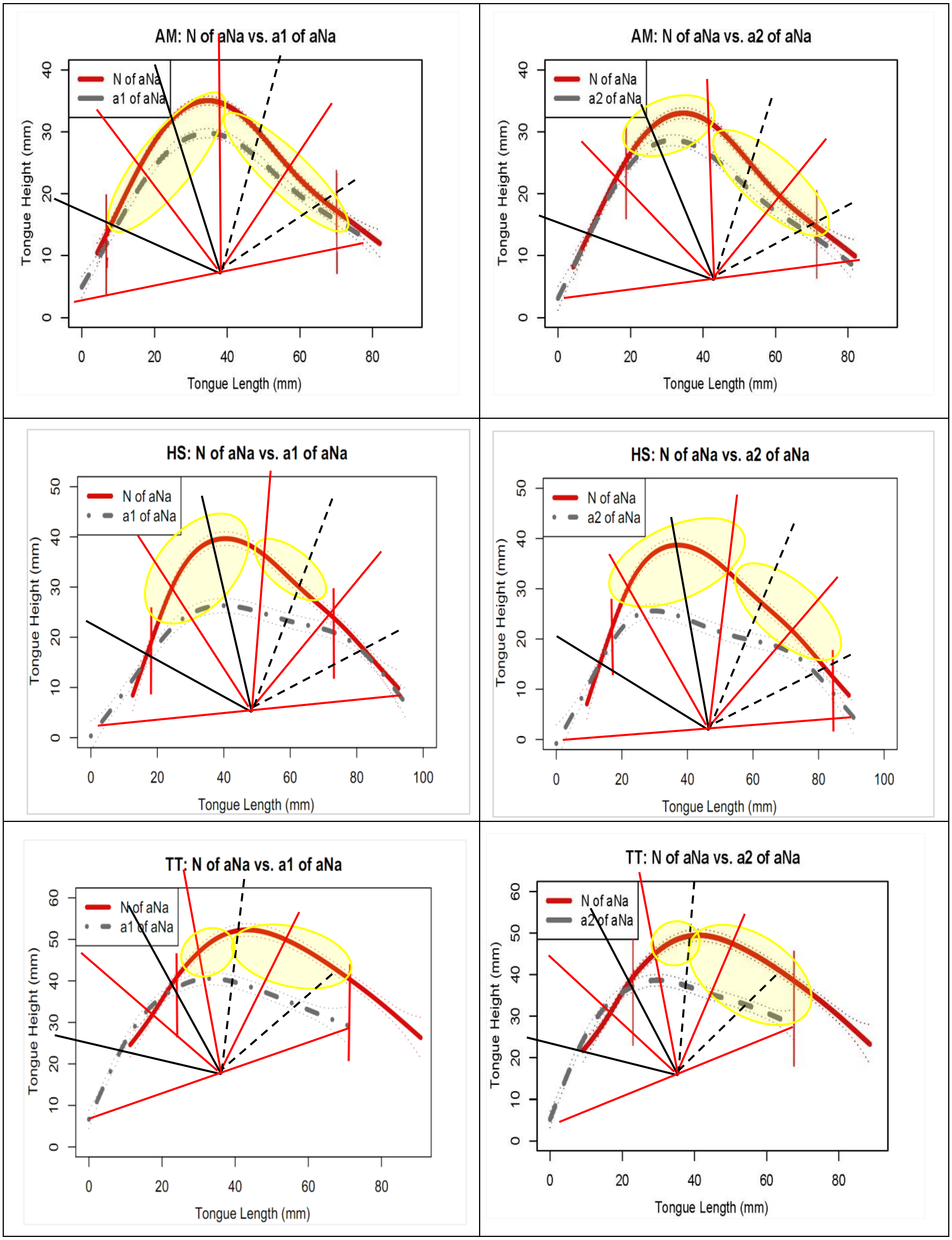


Figure 4.15. Application of the template to /N/: AM, HS, TT

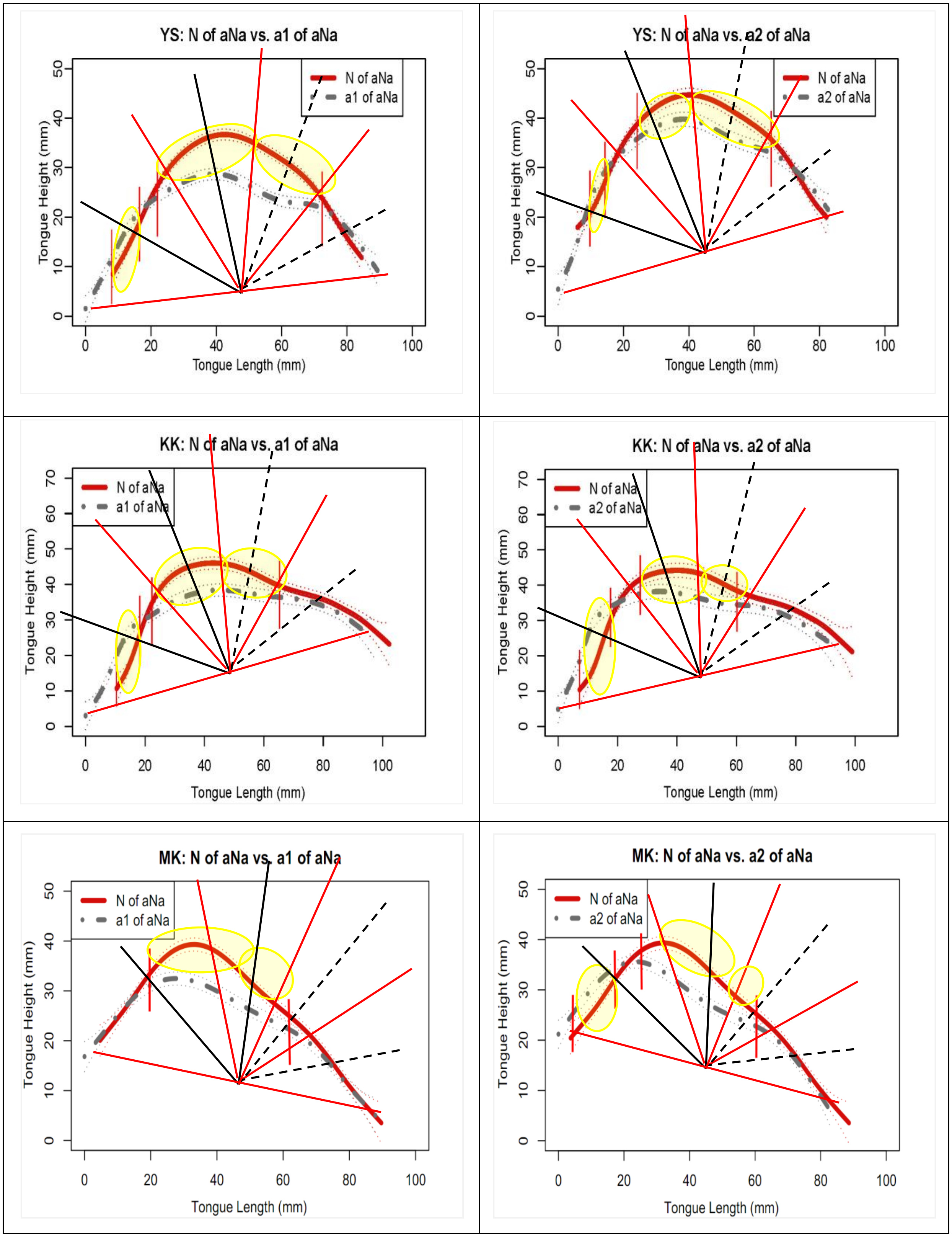


Figure 4.16. Application of the template to /N/: YS, KK, MK

The general finding of the analysis is that the constriction location has a much wider range compared to the one for /h/: The constriction of /h/ is found across 2-3 zones around the upper pharyngeal and uvular areas, while the constriction of /N/ is found across 4-5 zones around the velar area. This finding is compatible with the assumption that pharyngeal /h/ has tongue root retraction toward the pharyngeal wall, while /N/ has dorsum raising. The most posterior region of significant difference is found in the upper pharyngeal area, and the most anterior region of significant difference is found in the post-alveolar area.

The constriction location of /N/ for all speakers is summarized below. The subzones which show significant constriction are shaded in gray. Note that for /N/ to get a consonantal constriction, raising of the dorsum or retraction of the tongue root has to take place. In either case, some part of the tongue surface of /N/ should be located outside of the tongue surface of /a/. But the tongue is a muscular hydrostat, having a constant volume, so if the tongue body is raised, naturally the tongue root moves forward. The relation between tongue body height and tongue root advancement is formulated as the "grounded conditions" (Pulleyblank & Archangeli 1994: Chap. 3). We can see this condition is in effect in YS, KK, and MK, in the form of a significant difference in the pharyngeal subzones. But the significant difference in these subzones is a side effect of tongue body raising. Thus, in order to distinguish the zones having active constriction, I have shaded these cells with horizontal lines.

(4.2) Constriction location of /N/ relative to a1 and a2: all speakers

		phar		velar		palatal		alveolar	
AM	a1 vs. N	lower phar	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
	N vs. a2	lower phar	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
HS	a1 vs. N	lower phar	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
	N vs. a2	lower phar	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
TT	a1 vs. N	lower phar	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
	N vs. a2	lower phar	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
YS	a1 vs. N	~~lower phar~~	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
	N vs. a2	lower phar	~~upper phar~~	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
KK	a1 vs. N	~~lower phar~~	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
	N vs. a2	~~lower phar~~	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
MK	a1 vs. N	lower phar	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar
	N vs. a2	~~lower phar~~	upper phar	uvular	velar	palatal	pre-palatal	post-alveolar	alveolar

AM's constriction location ranges from upper pharyngeal to post-alveolar (6 zones), HS ranges from upper pharyngeal to post-alveolar (6 zones), TT ranges velar from to alveolar (5 zones), YS ranges from uvular to pre-palatal (4 zones), KK ranges from uvular to pre-palatal (4 zones), and MK ranges from upper pharyngeal to palatal (4 zones).

Now the problem is that it is impossible to specify a subzone as PoA – how can we decide PoA for cases where the significant difference straddles over multiple zones rather than a single zone? As a solution, the maximum constriction zone should be detected. This can be done simply by comparing subzones which include constriction. The greater the constriction is, the more the tongue surface of /N/ should go outward compared to the tongue surface of /a/.

As a solution, I propose to compare the constriction degree in each zone. See the example below (YS's a1 vs. /N/): The constriction covers zones of uvular, velar, postalveolar and alveolar. At first glance, it is not clear which area has the greatest constriction. So in each zone the line was manually drawn from the midpoint of /N/ to the midpoint of /a/ so that it could be extended toward the midpoint of the bottom line between tongue tip and tongue root.

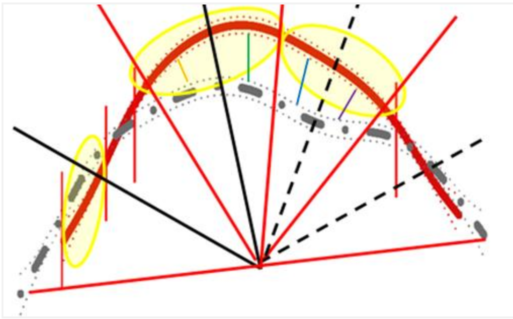


Figure 4.17. Lines between /N/ and /a/ in subzones showing significant difference

A violet line indicates constriction in the prepalatal subzone, blue indicates constriction in the palatal subzone, green indidates constriction in the velar subzone, and orange indicates constriction in the uvular subzone. The length of these lines was compared, and the longest line was found. If two lines happen to have the same length, then the areas showing the constriction were compared, and the larger subzone was taken as the maximum constriction subzone. The results are summarized below.

(4.3) Constriction location of /N/ relative to a1 and a2

	a1 vs. /N/	/N/ vs. a2
AM	velar	velar
HS	velar	velar
TT	post-alveolar	post-alveolar
YS	velar	palatal
KK	velar	palatal
MK	uvular	uvular

The results show that the maximum constriction subzone was in the range from post-alveolar to uvular.

The next thing we should ask is where the maximum constriction of /k/ is. This question arose from the relative position of /N/ presented in the previous section; /k/ seems to shift around /N/ among speakers. With the same procedure, SS-ANOVA tongue contour graphs of /akka/ were created for all the speakers (see Figure B 15 - Figure B 20 in Appendix). Based on the graphs, the maximum constriction location of /k/ relative to a1 and a2 was attained for each speaker. This is given below.

(4.4) Constriction location of /k/ relative to a1 and a2

	a1 vs. /k/	/k/ vs. a2
AM	uvular	uvular
HS	velar	velar
TT	palatal	prepalatal
YS	palatal	prepalatal
KK	palatal	prepalatal
MK	uvular	uvular

Four participants show /k/ is prepalatal, and the rest two participants suggest it is a bit farther back. AM's /k/ is more uvular, and KK's /k/ is around velar.

Recall that the tongue peak analysis in the previous section suggests that AM's and HS's /N/s are both more forward than /k/. A remaining question is whether each /N/ is different from /k/ in the location, especially because the distance between them is small - less than 3 mm. An answer from the template analysis above is that HS's /N, k/ share a position of velar, while AM's /N/ is velar but /k/ is uvular.

The table below shows (i) the relative position of the highest point of /N/ compared to /k/ (e.g., "before /k/ (2.99 mm)" indicates /N/ is more forward than /k/ by 2.99 mm) (ii) the maximum constriction points of each /N/ and /k/, and (iii) whether the result from (i) and the result from (ii) match with each other.

(4.5) Summary of two analyses and comparison

	(i) relative position of peak of /N/	(ii) maximum constriction relative to [a]		results in (i) & (ii) match?
		/N/	/k/	
AM	before /k/ (2.99 mm)	velar [ŋ˔]	uvular [q̘]	yes
HS	before /k/ (2.74 mm)	velar [ŋ˔]	velar [k̘]	yes
TT	after /k/ (5.32 mm)	post-alveolar [n˔]	palatal ~ prepalatal [k̘]	no
YS	after /k/ (3.43 mm)	velar ~ palatal [ŋ˔ ~ ɲ˔]	palatal ~ prepalatal [k̙]	yes
KK	after /k/ (5.29 mm)	velar ~ palatal [ŋ˔ ~ ɲ˔]	palatal ~ prepalatal [k̙]	yes
MK	after /k/ (3.43 mm)	uvular [ɴ˔]	uvular [q̙]	yes

Five out of six speakers results show that the result from peak analysis in (i) and the result from maximum constriction analysis in (ii) match with each other; For example, AM's /N/ is more forward than /k/ from (i), and this result makes sense from (ii) because in this speaker /N/ is velar and /k/ is uvular. Smiliarly YS's /N/ is farther back than /k/ from (i), and this result makes sense from (ii) because in this speaker /N/ is around velar and palatal, /k/ is around palatal and prepalatal. Only TT shows somewhat awkward results: The peak analysis suggests /N/ is farther back than /k/, but the maximum constriction analysis suggests the reverse. Since we are comparing the two locations which were attained by different metheods, this could be expected: the point which is farthest away from /a/ vs the peak of the tongue may not necessarily match. As I noted in the previous section, the peak of the tongue may just indicate the uvularity rather than the actual highest point of the tongue.

But overall, it was confirmed that i) the relative position of /N/ and /k/ are variable across speakers, and ii) the assumption that /k/ is velar aross speakers may be wrong: the location of /k/ is variable from prepalatal (prevelar) to uvular (postvelar) depending on the speaker. Another thing that was not expected is that variation of /k/ is not only a matter of prevelar or postvelar, but also a matter of advanced tongue root and retracted tongue root. This distinction is obvious in Figure B 15 – B 20 in Appendix. For tongue root advancers - AM, HS and TT - the tongue root of /k/ is more forward compared to /a/, while for tongue root retracters - YS, KK and MK - the tongue root of /k/ is farther back compared to /a/. Thus even if AM and MK both have [q], AM has retracted [q̠] and MK has advanced [q̟]. Likewise, even if HS and YS have both [k], HS has retracted [k̠], and YS has advanced [k̟].

4.3.3. Discussion of 4.3.

4.3 3.1. Different Location across Speakers and IPA issues

The results from CD suggest that /N/ is not targetless. Although the overall distribution of /N/ is in general slightly larger than those of /h/ and /k/, f-tests found no significant difference in /N/ vs. /h/ and /N/ vs. /k/ for 5 out of 6 talkers. The only exception is HS: IQR/SD of /N/ is significantly larger than those of /h/ or /k/, suggesting that this talker's /N/ is more variable than /h/ or /k/. Also, based on the fact that the boxplot area of /k/ is a subset of the boxplot area of /N/, we can imagine that HS's oral closure for /N/ is sometimes complete like /k/, and sometimes incomplete but not so loose as /h/.

The results of CL also suggest that /N/ is not targetless, and the target of the CL is as stable (within speaker) as that of /k/. By comparing the different tongue peaks, the target of CL ranges from post-alveolar to uvular.[61] This high degree of idiosyncrasy in place of articulation accounts for the variability observed across previous single-subject studies. It means that the descriptions in previous studies may be possibly correct.

But is there a single IPA symbol that is able to express the variability? This question is important because native speakers of Japanese auditorily categorize those different /N/s as the same phoneme, despite their PoAs being different.

[61] The variability across speakers can be also observed in the comparison of (i) aNa vs. ahha, (ii) aNa vs. akka. See Figures B.2-B.7 in Appendix.

The symbol called ‘Long-leg N’ [ƞ] was once suggested. Pullum & Ladusaw (1996: 120) state,

> Proposed in *Principles* […] for representing a syllabic alveolar nasal, particularly as in Japanese, or as a digraph for nasal vowels […]. IPA approval was withdrawn in 1976 […] because the symbol is purely phonological, being realized in Japanese by a number of different sounds. The symbol <n̩> is normally used for a syllabic [n].

The statement here has implied a few issues. First, [ƞ] ‘Long-leg N’ was declined, and since then there has been no appropriate symbol for Japanese /N/. We can also see that Japanese /N/ has been once categorized as alveolar, as <n̩> was suggested as an alternative, but currently the major view is that it is uvular rather than alveolar. Lastly, which /N/ is called “syllabic” may be problematic. Indeed, /N/ corresponds to one symbol of the Japanese native orthography of kana syllabary, ん, which supports /aNa/ being segmented as in /a.N.a/, but is phonologically syllabified as /aN.a/ where /N/ is in the coda of the first syllable. But even if we use dots and some well-established nasal symbol such as the uvular nasal, a transcription such as [aɴ.a] implies the nasal has a complete closure at the uvular PoA. Thus what is needed is to indicate that the oral closure is not complete, or weaker. For this purpose, the use of a diacritic - subscript arch - could be an option, as in [aɴ̯.a] (p.c. Joe Stemberger).[62]

Here are various symbols that have been suggested in the previous literature, but each has some problems and nothing has been established as Japanese /N/.

[62] The use of a lowering diacritic as in [aɴ̞a] could be another option, but consonant-like timing is not suggested.

(4.6) Suggested symbols

a.	[aNa]	Used in Trubetzkoy (1931[1971]), Ota (1965), Fujimura & Ooizumi (1972). N is not IPA, but archiphoneme.
b.	[aṽa]	Used in Kuroda (1979[1965]: 201-202). It conflicts with the labiodental fricative.
c.	[aãa]	Used in Nakano (1969), Yatabe (1987). The actual tongue position of N is not so low as [a].
d.	[aãˠa]	Double diacritics of nasalized and velarized?
e.	[aŊa]	Used in Kanehiro (1936), Sakuma (1929[1963]), Sakō (1979[1984]). Unfamiliar.
f.	[aə̃a]	Used in Uemura (1997a). Schwa may imply it has shorter duration.
g.	[aɣ̃a]	Used in Uemura & Takada (1990: 296, 514). N does not have friction like the velar fricative.
h.	[ana] [aŋa] [aɴa]	These symbols imply they have complete oral closure, but N does not.
i.	[aj̃a] [aɰ̃a] [aɦ̃a]	[ɦ̃] is used in de Lacy (2006), as interpretation of Trigo (1988). Nasalized approximants may be intuitive, but there is no uvular version, so we need to state [ɦ̃] is uvular.
j.	[aɲ̞a] [aŋ̞a] [aɴ̞a] [aɲ˕a] [aŋ˕a] [aɴ˕a]	The use of the lowering sign ˕ may be good, but it should be noted that the closure is incomplete. The use of the lowering sign under the symbol may make the sign invisible due to space issues. In such a case, the sign would look better when next to it.

The purpose of reviewing the symbols is not to propose new ones, but to pose questions (see also Ball & Rahilly 2011 for discsussion of semivowels and frinctionless continuants). In light of the experimental results showing different locations, we have shown that we may need different symbols for each /N/ to show different PoA.

4.3.3.2. Invariance of Place Hierarchy

The variability across speakers should not be taken as evidence of allophones. Allophones should show complementary distribution within a speaker, but it is not the case for /N/ in Japanese. The findings here should not be taken as free variation in a traditional sense either. Free variation should show that "two or more **phones** can appear in the same position without any effect upon meaning. For example, a single speaker of English may at various times pronounce the word *eat* with two or more of aspirated [tʰ], unaspirated [t⁼], glottalized [ʔt], or unreleased [t˺]" (Trask 1996: 150; emphasis original). The results in my experiment do not support the free variation under this definition, because the /N/ of a single speaker is no more variable than /h, k/.[63]

But the findings here may be categorized as free variation in a broader sense: "[l]ess commonly, the phenomenon in which either of two or more **phonemes** may be used in the same position in the same word without affecting meaning, as when *economics* or *evolution* may be pronounced either with initial /i:/ or initial /e/ (Trask 1996: 150; bold and italic original). In this less common definition, the two phonemes can be realized either by a single speaker or by multiple speakers. Thus the variation of /N/ across speakers attested here could be categorized as free variation in a broader sense. Once it is categorized as free variation, it may give the impression that multiple phonemes can show up freely and quite randomly. However, it has been shown that what seems to be a random phenomenon is actually more structured and constrained, which can be captured in the framework of OT (e.g., Antilla 1998, Itô & Mester 1997).

Whatever the category is, each individual has a different PoA for intervocalic /N/. This coda position is known as neutralized position, and the resulting PoA should be universally less marked than the input PoA. This tendency has been captured by universal constraints. In OT, all constraints are universal, and some constraint families have a hierarchy which is universally fixed. The place markedness hierarchy (Prince & Smolensky 1993[2004], Lombardi 1995, 2001) is such a hierarchy.

(4.5) Place markedness hierarchy:

*dor » *lab » *cor » *glot

This hierarchy is a problem for our data. It predicts that when neutralization occurs, the output should be less marked. de Lacy (2002a, 2006) states that with this hierarchy, it is predicted that neutralization to glottal or coronal will occur, but neutralization to dorsal should never occur.

But as I mentioned in sec. 1.2.1.2, coronal and labial are neutralized to /N/ in Japanese, and /N/ shows dorsum raising in the ultrasound images. So /N/ can be taken as Dorsal.

[63] I do not deny the possibility that variation between speakers may exist within an individual. See Rice (2004: 403-4) for examples of free variation.

According to Catford (1988: 79), the dorsum consists of two parts, and "[t]he front part of the dorsum (anterodorsum) practically always articulates against the roof of the mouth in the palatal zone, while the posterodorsum articulates in the velar zone." Thus a palatal/velar /N/ involves the dorsum.

de Lacy (2002a, 2006) claims that /N/ is not dorsal, but "non-placeless glottal". If /N/ is glottal, it would be no problem for the place hierarchy. But invariance of the place hierarchy has been questioned, and various ideas have been put forward. One drastic idea is that there is no such hierarchy, and the place hierarchy should be language-specific.[64] Alternatively, Pulleyblank (2004) suggests such a hierarchy may vary depending on phonological contexts such as prosodic positions. In fact, Bernhardt & Stemberger (1998) proposed a constraint that elements in rimes tend to have the Dorsal feature (see Trigo 1988, Howe 2004, Y. Rose 2003 for a compatible view.). Not only prosodic position but also manner features may also be considered. Nasal segments compared to oral segments may be combined with Dorsal more easily (see Baker, Mielke & Archangeli 2008, Itô & Mester 1997, Czaykowska-Higgins 1992, Rice 1996, 2007), but the exploration of this possibility is beyond the scope of this discussion.

4.3.3.3. Tightly Constrained Within a Speaker

One may want to ask how realistic it is to assume that the place of /N/ is tightly constrained within an individual. From the point of view of variationists, it is common to see that the variations between speakers may also occur in a single speaker (cf. Antilla 2002), so it seems reasonable to ask whether there is some parallelism between the interspeaker variation and variation within a speaker. The data obtained here is taken from a limited environment of an experimental setting, so once the speakers get out of the setting, they may use different articulatory strategies in various contexts. In other words, the experimental results here would not guarantee that speakers never diverge from their own pattern.

[64] It has been pointed out that /k/ is more frequent than /t/ in the Japanese inventory (cf. Kitahara 2008), which could be evidence for the unmarkedness of dorsal. But this is based only on voiceless stops, so if other segments are added in, coronal as a feature would be more frequent. In Tamaoka & Makioka's (2004) survey from a large corpus of text from newspapers, dorsals make up 22% of consonants, and coronals make up 62%. (Thanks to Joseph Stemberger for pointing this out.) However, de Lacy (2006: 31) states that text frequency is not a valid diagnostic for markedness, because it is heavily influenced by performance.

However, it seems wrong to assume that variation within a speaker cannot be obtained in a limited experimental setting. In Mielke, Archangeli & Baker's (2011) ultrasound experiment, articulatory variations within a speaker were actually obtained:

> In the face of ambiguous and unreliable perceptions of the multiple production strategies, speakers cannot converge on a common rule because no one knows for sure what anyone else is doing. Speakers are faced with a variety of choices: use one production strategy exclusively, vary randomly among production[~~s~~] strategies, or organize the production options into their own idiosyncratic system. Experiment #1 revealed examples of each: some speakers used only bunched or only retroflexed articulations, some varied among a subset of the articulations, and some (the focus of the above discussion) developed highly idiosyncratic patterns. (Mielke, Archangeli & Baker 2011: 720)

From this statement, we can see that the experimental setting is not really a decisive factor to limit the variation of the articulation. But what is interesting in Mielke et al.'s (2011) conclusion is whether having variation or not is a speaker's choice. Thus, in light of this viewpoint, the tightly constrained distribution of Japanese /N/ within a speaker cannot be due to the experimental setting. The distribution here would have to be interpreted as a choice of all the speakers who participated in this experiment.

In contrast to the American English /r/ experiment, the Japanese /N/ experiment demonstrated the distribution is tightly constrained for place. But it does not mean that every aspect of /N/ is tightly constrained within any single speaker: For CD, we can find more variation within a speaker. The data on CD show that some speakers have variation and others do not. This suggests that the range of degree may also be a choice for speakers. This idea is compatible with the observation of sound spectrographic evidence done by Nakaoka & Muraki (1990), who state that whether or not oral closure is formed in the production of /N/ depends on person, or even within a speaker, the degree of closure may be variable (Nakaoka & Muraki (1990: 145)).

Kingston (2007) discusses two ways of getting distinctive features to emerge out of phonetics: articulatorily or auditorily. But Kingston states that earlier studies suggesting variation between speakers of the articulation of bunched /r/ vs. retroflex /r/ among speakers of American English now can be interpreted as the results of aiming for the same auditory target – lowered F3, based on the observation that the constriction location and the overall configuration of the vocal tract are not same in these two articulations (p. 405).

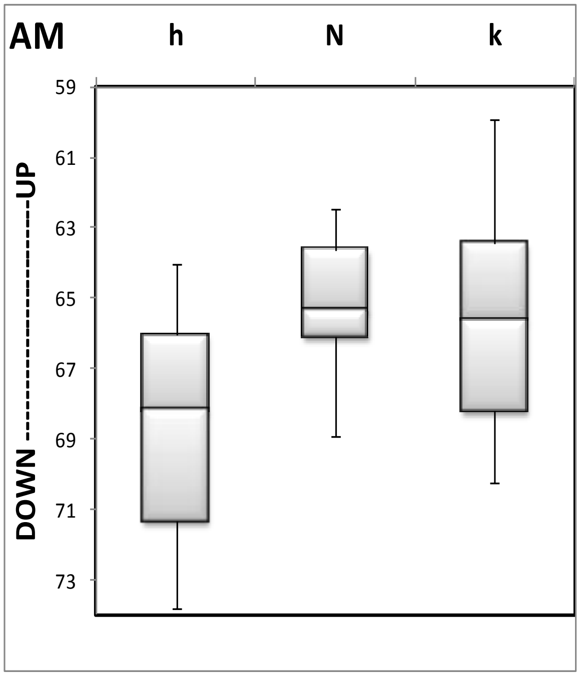
It would be interesting to ask how the choice of multiple strategies is available for features in general, and whether there is any systematic availability for the choices. All of this would be for future research.

4.4. Results of Targets across Contexts /a/ and /i/

This section reports on what happens when we combine the results of aCa and iCi, as opposed to keeping them separate. The data consist of (i) /h/ in /ahha/ plus /h/ in /ihhi/, (ii) /N/ in /aNa/ plus /N/ in /iNi/, and (iii) /k/ in /akka/ plus /k/ in /ikki/.

4.4.1. Constriction Degree

The graphs below show the CD (values of y-axis) of the peak of the tongue for (i) /h/ in /ahha/ plus /h/ in /ihhi/, (ii) /N/ in /aNa/ plus /N/ in /iNi/, (iii) /k/ in /akka/ plus /k/ in /ikki/. The results show that /h/ has the largest distribution among the three consonants for all speakers.

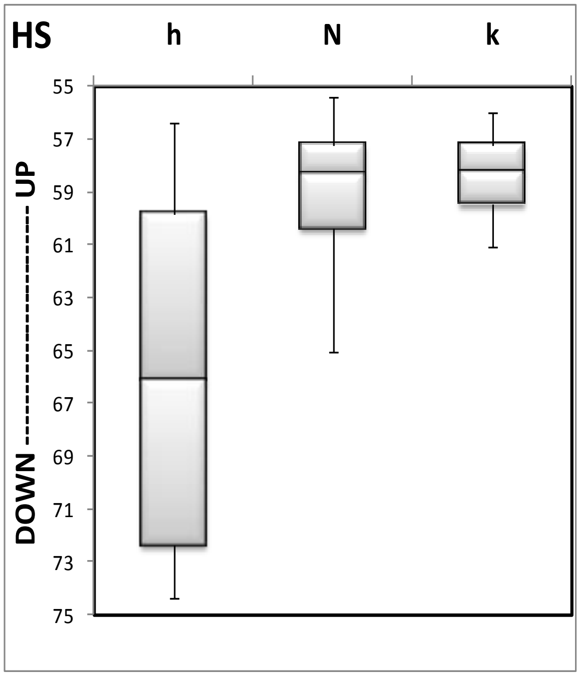


Labels	h	N	k
Mean	68.74	65.28	65.66
SD	**3.16**	1.78	2.93
Min	64.05	62.49	59.91
Q_1	66.05	63.6425	63.42
Median	68.19	65.345	65.63
Q_3	71.3125	66.105	68.195
Max	73.79	68.93	70.25
IQR	**5.2625**	2.4625	4.775

AM-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	0.33545533

Figure 4.18. Boxplots of constriction degree: AM: *V<u>hh</u>V*, *V<u>N</u>V*, and *V<u>kk</u>V*

In AM's speech with a pharyngeal /h/, /h/ has the largest IQR. The CD of /N/ is farther upward compared to /h/ and /k/, and the relative ranking of the constriction degree based on the mean is /N/ > /k/ > /h/. There is no significant difference between /N/ vs. /k/, suggesting that these may share a similar constriction degree target. The mean difference between /h/ and /N/ is 3.46 mm.

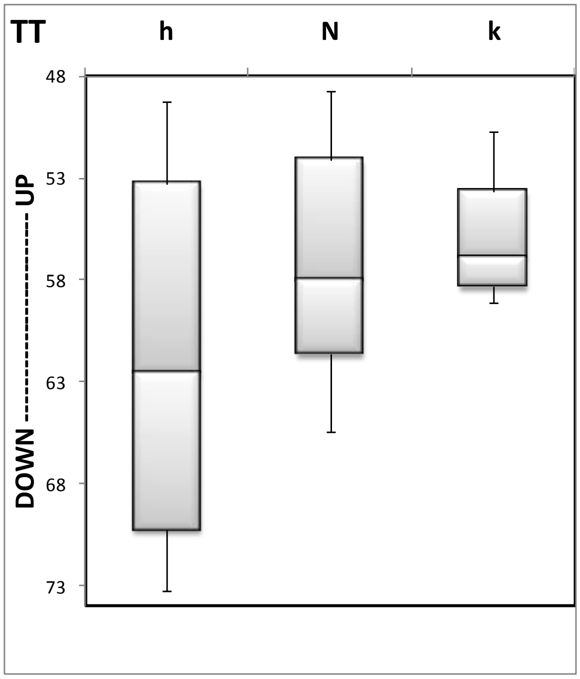


Labels	h	N	k
Mean	66.11	59.53	58.30
SD	**6.84**	3.79	1.40
Min	56.39	55.41	55.99
Q_1	59.8175	57.2025	57.2
Median	66.145	58.315	58.255
Q_3	72.36	60.355	59.42
Max	74.38	69.65	61.05
IQR	**12.5425**	3.1525	2.22

HS-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	0.09373173

Figure 4.19. Boxplots of constriction degree: HS: *VhhV*, *VNV*, and *VkkV*

In HS's speech with a dorso-pharyngeal /h/, the CD of /k/ is farther upward compared to /h/ and /N/, and the relative ranking of the constriction degree based on the mean is /k/ > /N/ > /h/. There is no significant difference between /N/ vs. /k/, suggesting that these may share a similar constriction degree target. The mean difference between /h/ and /k/ is 7.81 mm. /h/ has the largest IQR.

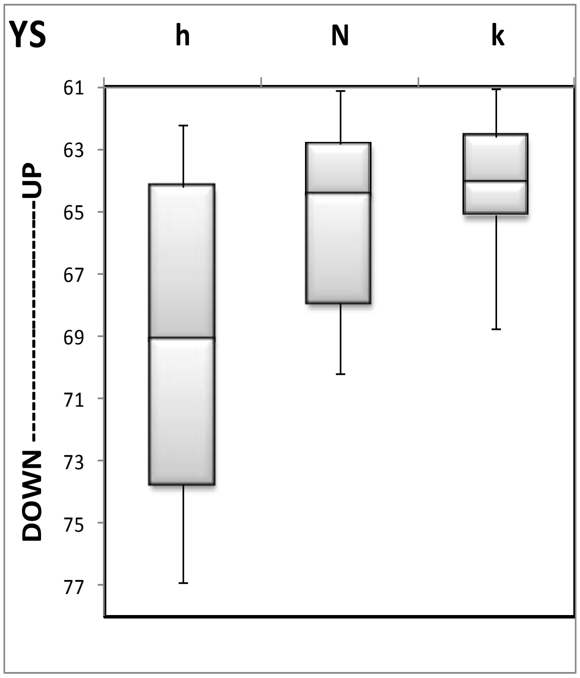


Labels	h	N	k
Mean	61.64	56.89	55.67
SD	**9.31**	5.42	2.96
Min	49.25	48.73	50.69
Q_1	53.2825	52.12	53.6475
Median	62.54	58.01	56.86
Q_3	70.2225	61.575	58.26
Max	73.21	65.43	59.12
IQR	**16.94**	9.455	4.6125

TT-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	0.16632242

Figure 4.20. Boxplots of constriction degree: TT: *V<u>hh</u>V*, *V<u>N</u>V*, and *V<u>kk</u>V*

In TT's speech with a dorso-pharyngeal /h/, the CD of /k/ is farther upward compared to /h/ and /N/, and the relative ranking of the constriction degree based on the mean is /k/ > /N/ > /h/. There is no significant difference between /N/ vs. /k/, suggesting that these may share a similar constriction degree target. The mean difference between /h/ and /k/ is 5.97 mm. /h/ has the largest IQR.

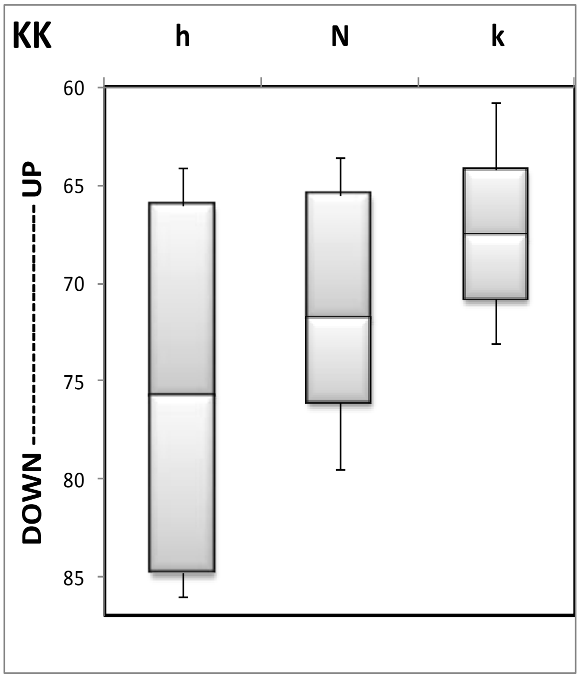


Labels	h	N	k
Mean	69.12	65.26	64.02
SD	**5.42**	2.98	1.92
Min	62.21	61.13	61.04
Q_1	64.205	62.8375	62.595
Median	69.135	64.45	64.09
Q_3	73.73	67.9125	65.0675
Max	76.92	70.21	68.78
IQR	**9.525**	5.075	2.4725

YS-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	$p < 0.05$

Figure 4.21. Boxplots of constriction degree: YS: *VhhV*, *VNV*, and *VkkV*

In YS's speech with a pharyngeal /h/, the CD of /k/ is farther upward compared to /h/ and /N/, and the relative ranking of the constriction degree based on the mean is /k/ > /N/ > /h/. There is a difference between every pair, suggesting that every segment may have a different target. The mean difference between /h/ and /k/ is 5.1 mm. /h/ has the largest IQR.

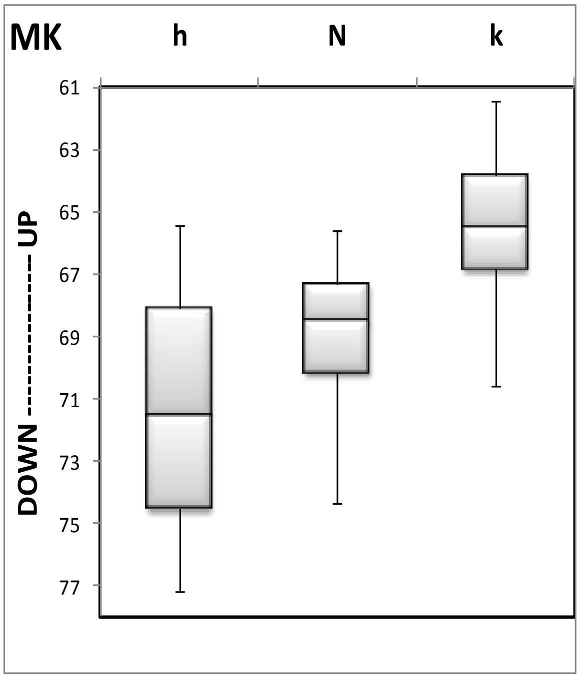


Labels	h	N	k
Mean	75.37	71.11	67.25
SD	**9.49**	5.77	3.75
Min	64.12	63.57	60.72
Q_1	66.03	65.505	64.2275
Median	75.735	71.785	67.625
Q_3	84.7425	76.0975	70.8275
Max	86.04	79.53	73.03
IQR	**18.7125**	10.5925	6.6

KK-y P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	$p < 0.001$
N vs. k	$p < 0.001$

Figure 4.22. Boxplots of constriction degree: KK: *VhhV*, *VNV*, and *VkkV*

In KK's speech with a dorsal/placeless /h/, the CD of /k/ is farther upward compared to /h/ and /N/, and the relative ranking of the constriction degree based on the mean is /k/ > /N/ > /h/. There is a difference between every pair, suggesting that every segment may have a different target. The mean difference between /h/ and /k/ is 8.02 mm. /h/ has the largest IQR.



Labels	h	N	k
Mean	71.46	69.26	65.59
SD	**3.92**	2.78	2.18
Min	65.45	65.62	61.46
Q_1	68.1	67.3225	63.835
Median	71.545	68.505	65.545
Q_3	74.5025	70.1425	66.8275
Max	77.17	76	70.6
IQR	**6.4025**	2.82	2.9925

MK-y P-value (t-test)	
h vs. N	$p < 0.005$
h vs. k	$p < 0.001$
N vs. k	$p < 0.001$

Figure 4.23. Boxplots of constriction degree: MK: *V<u>hh</u>V*, *V<u>N</u>V*, and *V<u>kk</u>V*

In MK's speech with an dorso-pharyngeal /h/, the CD of /k/ is farther upward compared to /h/ and /N/, and the relative ranking of the constriction degree based on the mean is /k/ > /N/ > /h/. There is a difference between every pair, suggesting that every segment may have a different target. The mean difference between /h/ and /k/ is 5.87 mm. /h/ has the largest IQR.

The difference in the constriction degree between /N/ vs. /k/ or /N/ vs. /h/ is confirmed using t-tests, as summarized in Table 4.10. /N/ vs. /h/ and /h/ vs. /k/ are significantly different for all speakers, but /N/ vs. /k/ is significantly different for 2 out of 6 speakers. [65] I suggest that the default constriction of /N/ of AM, HS and TT is in a similar range to /k/.

Table 4.10. T-test (unpaired) of constriction degree for *V<u>hh</u>V*, *V<u>N</u>V*, and *V<u>kk</u>V* (P-values)

CD a&i	AM	HS	TT	YS	KK	MK
N vs. h	<.001	<.001	<.001	<.001	<.001	<.005
h vs. k	<.001	<.001	<.001	<.001	<.001	<.001
N vs. k	NS	NS	NS	<.05	<.001	<.001

For the purpose of measuring the variability of CD, Standard Deviation (SD) and IQR of the y values at the peak of the tongue were compared among /h, N, k/. For every speaker, /h/ is the most variable, and the rankings of /N/ and /k/ have some variation. But the average of SD and the average of IQR show the same result: The ranking of variability is /h/ > /N/ > /k/, as in the two tables below.

Table 4.11. Standard deviations of constriction degree for *V<u>hh</u>V*, *V<u>N</u>V*, and *V<u>kk</u>V*

CD a&i	AM	HS	TT	YS	MK	KK	AVG
h SD	**3.16**	**6.84**	**9.31**	**5.42**	**3.92**	**9.49**	**6.36**
N SD	1.78	3.79	5.42	2.98	2.78	5.77	3.75
k SD	2.93	1.4	2.96	1.92	2.18	3.75	2.52

[65] Once we correct these P-values (Bonferroni), then YS will also come out as non-significant for N vs. k.

Table 4.12. IQR of constriction degree for *V<u>hh</u>V*, *V<u>N</u>V*, and *V<u>kk</u>V*

CD a&i	AM	HS	TT	YS	MK	KK	AVG
h IQR	**5.26**	**12.54**	**16.94**	**9.53**	**6.40**	**18.71**	**11.56**
N IQR	2.46	3.15	9.46	5.08	2.82	10.59	5.59
k IQR	4.78	2.22	4.61	2.47	2.99	6.60	3.95

For SD, 5 out of 6 talkers have the ranking /h/ > /N/ > /k/. Only AM shows /h/ > /k/ > /N/. For IQR, 4 out of 6 talkers have the ranking /h/ > /N/ > /k/. AM and MK show /h/ > /k/ > /N/.

The results of F-tests as in Table 4.13. show that the variance of every pair is significantly different for most speakers. But for AM, no significance was found in /h/ vs. /k/, and for MK, no significance was found in /h/ vs. /N/ and /N/ vs. /k/.

Table 4.13. F-tests of variance of constriction degree for *V<u>hh</u>V*, *V<u>N</u>V*, and *V<u>kk</u>V* (P-values)

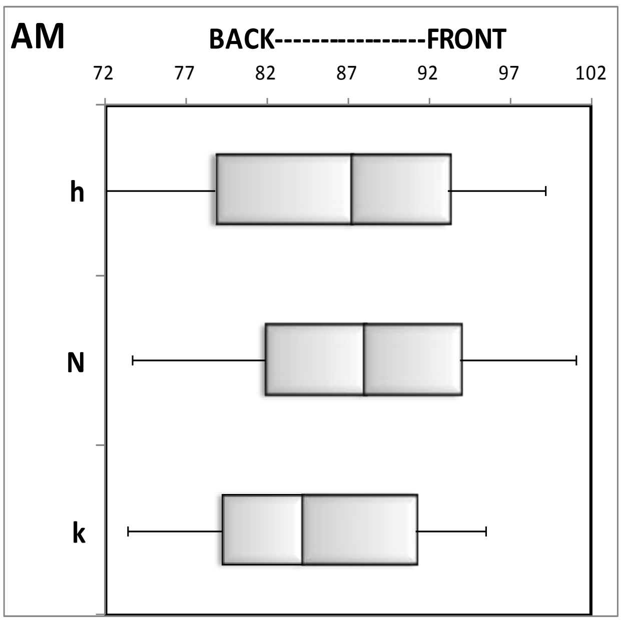
CD a&i	h vs. N	N vs. k	h vs. k
AM	0.008	0.020	0.725
HS	0.006	0.000	0.000
TT	0.012	0.005	0.000
YS	0.006	0.040	0.000
MK	0.106	0.251	0.007
KK	0.021	0.044	0.000

It seems the results simply reflect the fact that /h/ varies allophonically (palatal fricative before /i/, something much more back and "low" otherwise), whereas neither /N/ nor /k/ does. So the notable finding is that /N/ patterns like /k/ in not having the exact same allophonic-variation pattern as /h/ does.

The relative size of the SD/IQR of CD is same for all speakers: /h/ > /N/ > /k/. This suggests that /h/ is most variable depending on the vowel contexts.

4.4.2. Constriction Location

The graphs below show the CL (values of x-axis) of the peak of the tongue for (i) /h/ in /ahha/ plus /h/ in /ihhi/, (ii) /N/ in /aNa/ plus /N/ in /iNi/, and (iii) /k/ in /akka/ plus /k/ in /ikki/. The results in general show that for all speakers, the distribution of /h/ is larger than the distribution of /N/ or /k/.

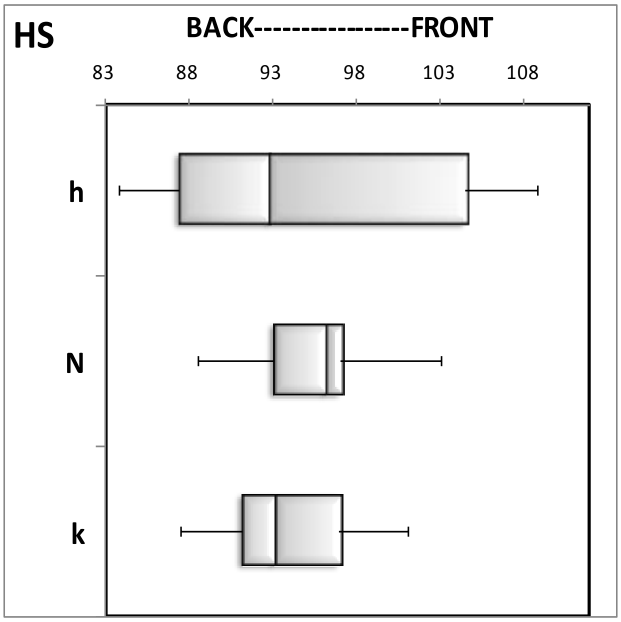


Labels	h	N	k
Mean	86.13	87.99	84.84
SD	**8.49**	7.58	7.17
Min	71.44	73.71	73.43
Q_1	78.86	81.9225	79.26
Median	87.225	88.015	84.145
Q_3	93.1875	93.9225	91.1825
Max	99.24	101.13	95.57
IQR	**14.3275**	12	11.9225

AM-x P-value (t-test)	
h vs. N	$p < 0.001$
h vs. k	0.07772025
N vs. k	$p < 0.001$

Figure 4.24. Boxplots of constriction location: AM: *VhhV*, *VNV*, and *VkkV*

In AM's speech with a pharyngeal /h/, /h/ has the largest IQR and SD. Since each boxplot includes a bar to indicate the median, we can use this to compare the three segments. Based on the medians, the CL of /N/ is farther forward compared to /h/ and /N/, and the relative ranking of the frontness of the location based on the mean is /N/ > /h/ > /k/. The mean difference between /N/ and /k/ is 3.15 mm. There is no difference between /h/ vs. /k/, suggesting that they may share a location target.

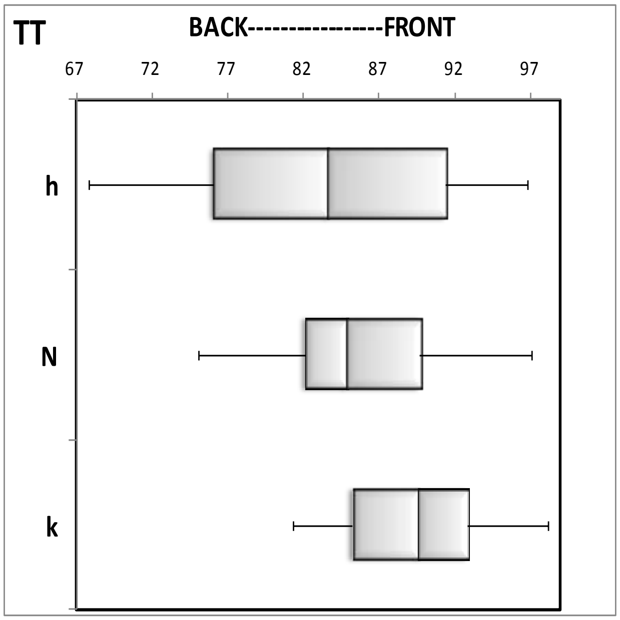


Labels	h	N	k
Mean	95.06	96.00	93.87
SD	**8.73**	4.49	3.44
Min	83.88	88.65	87.59
Q_1	87.45	93.14	91.2225
Median	92.835	96.235	93.195
Q_3	104.6075	97.1575	97.0675
Max	108.92	111.11	101.16
IQR	**17.1575**	4.0175	5.845

HS-x P-value (t-test)	
h vs. N	0.56027453
h vs. k	0.38287943
N vs. k	$p < 0.01$

Figure 4.25. Boxplots of constriction location: HS: *V<u>hh</u>V*, *V<u>N</u>V*, and *V<u>kk</u>V*

In HS's speech with a dorso-pharyngeal /h/, /h/ has the largest IQR and SD. As for the median, the CL of /N/ is farther forward compared to /h/ and /N/, and the relative ranking of the frontness of the location based on the mean is /N/ > /h/ > /k/. The mean difference between /N/ and /k/ is 2.13 mm. There is a significant difference between /N/ vs. /k/, suggesting that they have different location targets.

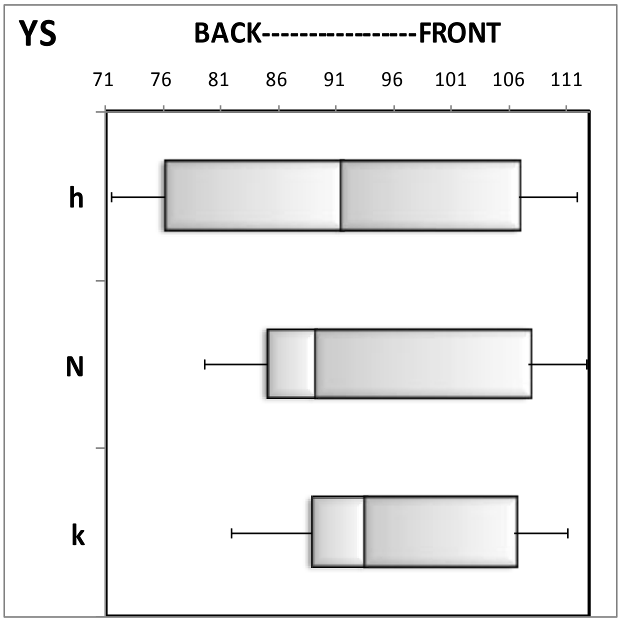


Labels	h	N	k
Mean	83.68	85.77	89.37
SD	**8.46**	5.30	4.75
Min	67.91	75.18	81.44
Q_1	76.1025	82.1675	85.3225
Median	83.645	84.88	89.605
Q_3	91.435	89.735	92.8625
Max	96.91	97.18	98.22
IQR	**15.3325**	7.5675	7.54

TT-x P-value (t-test)	
h vs. N	0.14107497
h vs. k	$p < 0.005$
N vs. k	$p < 0.001$

Figure 4.26. Boxplots of constriction location: TT: *VhhV*, *VNV*, and *VkkV*

In TT's speech with a dorso-pharyngeal /h/, /h/ has the largest IQR and SD. As for the median, the CL of /k/ is farther forward compared to /h/ and /N/, and the relative ranking of the frontness of the location based on the mean is /k/ > /N/ > /h/. The mean difference between /k/ and /h/ is 5.69 mm. There is a significant difference between /h/ vs. /k/ and /N/ vs. /k/, suggesting that they have different location targets.

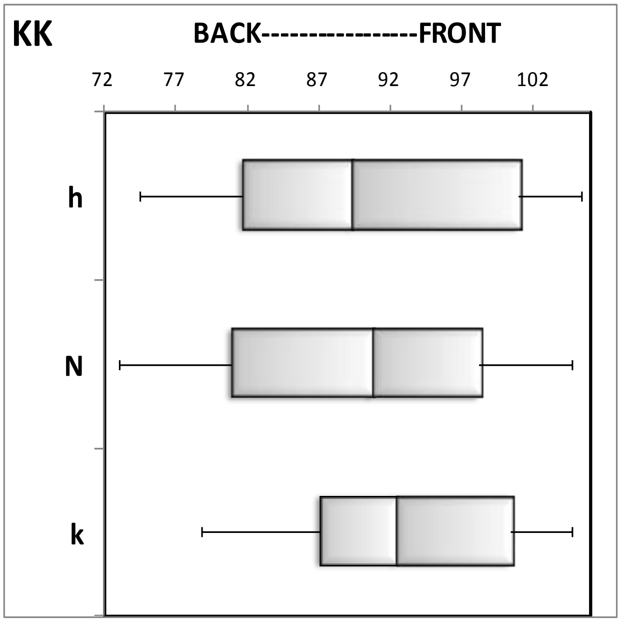


Labels	h	N	k
Mean	91.79	95.42	97.11
SD	**15.92**	11.58	9.85
Min	71.59	79.64	82.01
Q_1	76.275	85.1	88.94
Median	91.475	89.2	93.5
Q_3	106.9075	107.795	106.5275
Max	112.03	112.79	111.21
IQR	**30.6325**	22.695	17.5875

YS-x P-value (t-test)	
h vs. N	$p < 0.02740103$
h vs. k	$p < 0.005$
N vs. k	0.2430779

Figure 4.27. Boxplots of constriction location: YS: *VhhV*, *VNV*, and *VkkV*

In YS's speech with a pharyngeal /h/, /h/ has the largest IQR and SD. As for the median, the CL of /k/ is farther forward compared to /h/ and /N/, and the relative ranking of the frontness of the location based on the mean is /k/ > /N/ > /h/. The mean difference between /k/ and /h/ is 5.32 mm. There is a significant difference between /h/ vs. /k/, suggesting that they have different location targets.

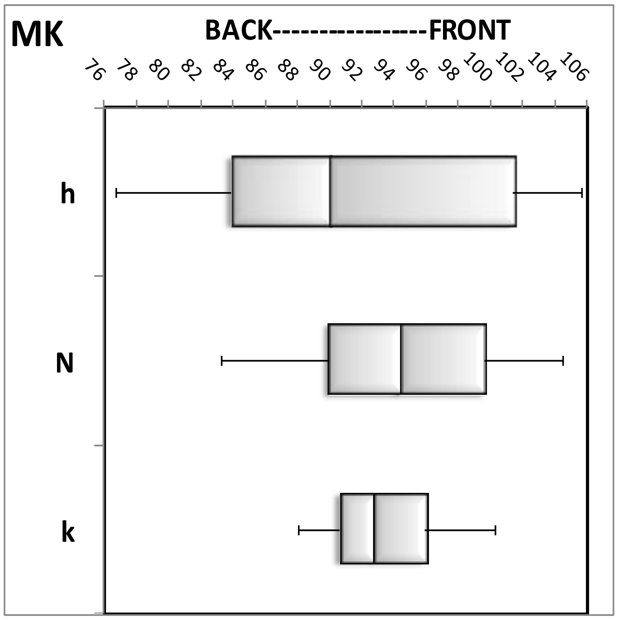


Labels	h	N	k
Mean	90.78	89.79	93.09
SD	**10.07**	9.95	7.78
Min	74.6	73.17	78.9
Q_1	81.7325	80.98	87.1575
Median	89.34	90.785	92.455
Q_3	101.05	98.33	100.4825
Max	105.51	104.86	104.8
IQR	**19.3175**	17.35	13.325

KK-x P-value (t-test)	
h vs. N	0.38090875
h vs. k	0.05200889
N vs. k	$p < 0.005$

Figure 4.28. Boxplots of constriction location: KK: *VhhV*, *VNV*, and *VkkV*

In KK's speech with a placeless/dorsal /h/, /h/ has the largest IQR and SD. As for the median, the CL of /k/ is farther forward compared to /h/ and /N/, and the relative ranking of the frontness of the location based on the mean is /k/ > /h/ > /N/. The mean difference between /k/ and /N/ is 3.3 mm. There is a significant difference between /N/ vs. /k/, suggesting that they have different location targets.



Labels	h	N	k
Mean	92.02	95.00	93.25
SD	**9.35**	6.24	3.16
Min	76.78	83.34	88.09
Q_1	83.9575	89.985	90.7125
Median	90.03	94.415	92.805
Q_3	101.48	99.6275	95.99
Max	105.75	104.57	100.4
IQR	**17.5225**	9.6425	5.2775

MK-x P-value (t-test)	
h vs. N	$p < 0.01$
h vs. k	0.51112458
N vs. k	0.16537408

Figure 4.29. Boxplots of constriction location: MK: *VhhV*, *VNV*, and *VkkV*

In MK's speech with a dorso-pharyngeal /h/, /h/ has the largest IQR and SD. As for the median, the CL of /N/ is farther forward compared to /h/ and /k/, and the relative ranking of the frontness of the location based on the mean is /N/ > /k/ > /h/. The mean difference between /N/ and /h/ is 2.98 mm. There is a significant difference between /h/ vs. /N/, suggesting that they have different location targets.

The distribution of /N/ is similar to /h/ for 3 speakers (HS, TT, KK), but similar to /k/ for 2 speakers (KK, MK) as shown in Table 4.14.

Table 4.14. T-test (unpaired) of constriction location for *VhhV*, *VNV*, and *VkkV* (P-values)

CL a&i	AM	HS	TT	YS	KK	MK
N vs. h	$p < 0.001$	0.560	0.141	0.027	0.381	$p < 0.01$
h vs. k	0.078	0.383	$p < 0.005$	$p < 0.005$	0.052	0.511
N vs. k	$p < 0.001$	$p < 0.01$	$p < 0.001$	0.243	$p < 0.005$	0.165

For the purpose of measuring the variability of CL, Standard Deviation (SD) and IQR of x values at the peak of the tongue were compared among /h, N, k/. For every speaker, SD of /h/ is the largest. The average of SD and the average of IQR show a parallel result: The ranking of SD is /h/ > /N/ > /k/. This is shown in Table 4.15. and Table 4.16.

Table 4.15. Standard deviations of constriction location for *VhhV*, *VNV*, and *VkkV* (P-values)

CL a&i	AM	HS	TT	YS	MK	KK	AVG
h SD	**8.49**	**8.73**	**8.46**	**15.92**	**9.35**	**10.07**	**10.17**
N SD	7.58	4.49	5.30	11.58	6.24	9.95	7.52
k SD	7.17	3.44	4.75	9.85	3.16	7.78	6.02

Table 4.16. IQR of constriction location for *VhhV*, *VNV*, and *VkkV*

CD a&i	AM	HS	TT	YS	MK	KK	AVG
h IQR	**14.33**	**17.16**	**15.33**	**30.63**	**17.52**	**19.32**	**19.05**
N IQR	12.00	4.02	7.57	22.70	9.64	17.35	12.21
k IQR	11.92	5.85	7.54	17.59	5.28	13.33	10.25

For SD, every speaker has the same ranking, /h/ > /N/ > /k/. For IQR, 5 out of 6 speakers show the same ranking, /h/ > /N/ > /k/, but only HS shows /h/ > /k/ > /N/.

For the measurement of variance of CL, f-tests were conducted as below.

Table 4.17. F-tests of variance of constriction location for *V<u>hh</u>V*, *V<u>N</u>V*, and *V<u>kk</u>V* (P-values)

CL a&i	h vs. N	N vs. k	h vs. k
AM	0.594	0.787	0.423
HS	0.002	0.207	0.000
TT	0.029	0.599	0.008
YS	0.134	0.445	0.025
MK	0.058	0.002	0.000
KK	0.955	0.246	0.224

The most conspicuous result here is that the variance of /h/ vs. /k/ is significantly different for at least 3 speakers (HS, TT, MK), suggesting that /h/ is significantly more variable than /k/.

A significant difference was also found in the variance of /h/ vs. /N/ for HS (and possibly TT), suggesting that /h/ is significantly more variable than /N/. Lastly, a significant difference was found in the variance of /N/ vs. /k/ only for MK, suggesting that /N/ is significantly more variable than /k/.

To summarize, no strong evidence is found to support that /N/ is more variable than /k/. Although /N/'s variability is smaller than /h/ and larger than /k/ in the averages of SD and IQR, f-tests show that 5 out of 6 talkers have no significant difference in variance between /N/ vs. /h/ and /N/ vs. /k/.

4.4.3. Discussion of 4.4.

4.4.3.1. Wider Range and Placelessness

The wider range hypothesis was examined by SD and IQR in the two contexts. The following is the result of the /a/ context. The average of the 6 speakers' SD is shown in Table 4.18., and the average of those speakers' IQR is shown in Table 4.19.

Table 4.18. Average of SD: CD and CL in /a/ context

context-a	CD AVG	CL AVG
h SD	1.31	3.36
N SD	**2.26**	**3.38**
k SD	1.60	3.28

Table 4.19. Average of IQR: CD and CL in /a/ context

context-a	CD AVG	CL AVG
h IQR	1.78	**4.07**
N IQR	**2.95**	3.83
k IQR	2.16	3.77

As for the CD, the ranking of variability is /N/ > /h/ > /k/, which is supported by both SD and IQR. But as for CL, the ranking is /N/ > /h/ > /k/ by SD, while it is /h/ > /N/ > /k/ by IQR. When we look at the values of CL, there is no big difference among the three segments. The wide variability for CD will make sense if we consider /N/'s manner is undetermined, and the closure is weak or incomplete. The variable nature of /N/'s manner seems to be reflected in the SD of CD. On the other hand, as mentioned in sec 4.3.1, the CL of /N/ is quite stable, so there is no big difference between /N/ and others.

When the variability is measured in multiple contexts (/a/ and /i/ contexts), the ranking is /h/ > /N/ > /k/, which is stable for both CD and CL and in both measures of SD and IQR. The averages of all speakers from Table 4.11 and Table 4.15 are repeated and combined below.

Table 4.20. Average of SD: CD and CL in multiple contexts

context-a&i	CD AVG	CL AVG
h SD	**6.36**	**10.17**
N SD	3.75	7.52
k SD	2.52	6.02

Table 4.21. Average of IQR: CD and CL in multiple contexts

context-a&i	CD AVG	CL AVG
h IQR	**11.56**	**19.05**
N IQR	5.59	12.21
k IQR	3.95	10.25

The ranking /h/ > /N/ > /k/ in both CL and CD suggests that overall, /h/ is the most variable among three segments. This result would be reasonable from the allophonic rule that /h/ becomes a palatal fricative before /i/, by which CD and CL would be affected.

We conclude that /N/ is the most variable in CD in mono-context, and /h/ is the most variable in both CD and CL in multiple-context. This study presented data for the intervocalic position a_a and i_i only. Here the flanking vowels are identical, but if the vowels are different, e.g., a_i, i_a, o_i, e_o, the result may be different. Cohn’s (1990, 1993) nasal flow experiment detected a cline-type line of nasal flow when the featural specifications are opposite, e.g., [+nas]_[-nas]. The contextual variability can also consider other factors such as intervocalic vs. prepausal position or accented vs. unaccented position, and all of these can be used as raw data for the examination of variability. This has to be left for future research.

4.4.3.2. Inventory-Driven Specification of /h/

This section discusses the current results for /h/ from the viewpoint of the inventory-driven hypothesis for laryngeals proposed by Rose (1996). Rose argues that whether /h/ is placeless or place-specified is predictable from another aspect of the grammar: the segment inventory. I call this hypothesis the Inventory-driven hypothesis for laryngeals.

(4.6) Inventory-driven hypothesis for laryngeals (Rose 1996: 73)

Laryngeals are specified as Pharyngeal only when pharyngeals or uvular continuants are also present in the inventory of the language; otherwise, they are Placeless.

Pharyngeal /h/ is expected to pattern with pharyngeals and uvulars, and this pattern is seen in Arabic and Hebrew (Semitic) (McCarthy 1994), Nisgha (Tsimshianic) (Shaw 1991) and Gitksan (Rigsby 1986), and Iraqw (Cushitic) (Mous 1993). This way of specifying a pharyngeal node for /h/ is basically supported by the Node Activation Convention (Avery & Rice 1989a, b), which states that a featural node must be activated only when it is contrastive.

An opposing view is that whether laryngeals are placeless or place-specified has nothing to do with the segment inventory, and has to be stipulated on a language-specific basis. McCarthy (1991) takes this stance, presenting the data from Tigre (Ethiopic Semitic), where ejectives and pharyngeals lower vowels while /h/ does not. Bessell (1992) and Bessell & Czaykowska-Higgins (1992) also take this position, and argue that laryngeals are placeless in Thompson, Moses-Columbian Salish and Lillooet (Interior Salish), in spite of the rich guttural inventory including six uvulars, four voiced pharyngeals and two laryngeals.[66]

In the Japanese situation, it is only /N/ that is a potential pharyngeal or uvular continuant. Now the prediction would be that if /N/ is a pharyngeal or uvular continuant, then /h/ should be pharyngeal, otherwise /h/ is placeless. The prediction is illustrated below, showing possible combinations of /N/ and /h/. (The featural structures of segments are based on Rose 1996.)

(4.7) Possible combinations for /N, h/

<table>
<tr><td colspan="2">(i) Phar vs. Phar</td><td colspan="2">(ii) uvular vs. Phar</td><td colspan="2">(iii) velar vs. placeless</td></tr>
<tr><td>***N***
ROOT
|
Pl
|
Phar
|
[RTR]</td><td>***h***
ROOT
|
Pl
|
Phar</td><td>***N***
ROOT
|
Pl
|
Phar
/ \
Dor [RTR]</td><td>***h***
ROOT
|
Pl
|
Phar</td><td>***N***
ROOT
|
Pl
|
Dor</td><td>***h***
ROOT</td></tr>
</table>

(4.7i) shows the case where /N/ is pharyngeal, while (4.7ii) shows the case where /N/ is uvular. In both cases, the node pharyngeal is already activated so /h/ should also have it. (4.7iii) shows the case in which /N/ is dorsal. In this case the pharyngeal node is not activated, so there is no need to specify it.

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[66] However, Rose (1996) states that evidence for placelessness in these languages is not fully supported. For example, in Moses-Columbian, the /ə, a/ distinction is neutralized before /ʔ/ (Bessell 1992: 91), and in Lillooet, /a/ rather than /ə/ is realized before /ʔ/ (Shaw, Blake, Campbell & Shepherd 1999). In Rose's view, these phenomena can be considered as subtle retraction/lowering triggered by the pharyngeal node of laryngeals.

(4.8) Impossible combinations for /N, h/

(i) Phar vs. placeless		(ii) uvular vs. placeless		(iii) velar vs. Phar	
N ROOT | Pl | Phar | [RTR]	***h*** ROOT	***N*** ROOT | Pl | Phar / \\ Dor [RTR]	***h*** ROOT	***N*** ROOT | Pl | Dor	***h*** ROOT | Pl | Phar

In contrast, combinations such as (4.8i) pharyngeal nasal and placeless laryngeal, (4.8ii) uvular nasal vs. placeless laryngeal, or (4.8iii) velar nasal and pharyngeal laryngeal should never occur.

(4.9) Relation between PoA of /N/ and PoA of /h/

	place of N	Predicted place of /h/	place of /h/ found in experiment	Predicted result?
AM	velar [ŋ˕]	Placeless	pharyngeal [ħ]	no
HS	velar [ŋ˕]	Placeless	dorso-pharyngeal /uvular [χ]	no
TT	post-alveolar [n˕]	Placeless	dorso-pharyngeal /uvular [χ]	no
YS	velar [ŋ˕], palatal [ɲ˕]	Placeless	pharyngeal [ħ]	no
KK	velar [ŋ˕], palatal [ɲ˕]	Placeless	placeless or dorsal [x]	yes
MK	uvular [ɴ˕]	pharyngeal	dorso-pharyngeal /uvular [χ]	yes

Oral Guttural (post-velar)

5 out of 6 speakers have a non-guttural /N/ – Velar (AM, HS), post-alveolar (TT), velar and palatal (YS, KK) – so the pharyngeal node does not need to be activated. Then in these speakers /h/ is expected to be placeless. But contrary to the expectation, 4 out of 5 speakers have non-placeless /h/: AM and YS having pharyngeal [ħ] and HS, TT having uvular [χ], which roughly fit the impossible pattern in (4.8 iii). Only KK is placeless as predicted from the non-guttural /N/, which fits the pattern in(4.7 iii). In contrast, MK has a uvular /N/, and Japanese /N/ has no

complete oral closure therefore it is a uvular continuant. Then MK's /h/ is expected to be guttural. This is what we observed, which fits the pattern in (4.7 ii).

The results show that an inventory-driven specification of /h/ is not supported: If the inventory-driven hypothesis is correct, none of the combinations in (4.7) should be obtained. But these unpredicted cases were found for four (AM, HS, TT, YS) out of the six talkers' grammars. More data may strengthen the validity of this conclusion.

4.5. Conclusion

Multiple case studies were conducted in order to examine the target and variability of three segments /h, N, k/. The test was designed to obtain the variability within token and the variability across tokens, and the general results from two kinds of variability are not same. In the /a/ context, the CD of /N/ has the highest variability. The CL of /N/, on the other hand, does not show consistent results between SD and IQR: No solid evidence suggests that CL of /N/ is more variable compared to /h/ and /k/. In multiple contexts of /a/ and /i/, /h/ showed the most variable CD and CL, both in SD and IQR.

It was confirmed that /N/ has a place-specification for all speakers, but the place of /N/ as well as the place of /k/ turned out to be different across speakers. The distribution of CL values of /N/ is tightly constrained compared to the other segments. This is surprising, because it is against the general belief that the place of /N/ might be freely variable within a speaker. Thus, /N/ is not placeless, but the target of CD for /N/ is most variable within the mono-context, so that it could be categorized as a glide or an approximant.

The conclusion that individuals have different place features for /N/ or /k/ (or the relative position between them) may conflict with some versions of generative phonology where features and constraints are universally determined. There are 'prototypical' segments for a feature, and Mielke (2008) states that UG is not good for accounting for the non-prototypical segments such as nasals and liquids. They are phonetically ambiguous between continuant and noncontinuant, thus the phonological patterns are expected to be variable as well. In some languages the effect is so obvious that we can hear the difference, but in other languages, the effect is audibly indistinct and may be only instrumentally distinct. These are both called 'covert feature effects' (see Pulleyblank 2003, Kim & Pulleyblank 2009 for phonological evidence, Scobbie et al. 2000, Li, Edwards & Beckman 2009 for experimental evidence).

In this study, the application of ultrasound made such idiosyncratic articulatory data accessible and analyzable. Such individual variation of place can account for the existing multiple transcriptions that apparently conflict. Similar variations across individuals are attested in /r/ of American English (Mielke, Baker & Archangeli 2011). Since nasals and liquids are non-prototypical consonants, phonetic ambiguities may motivate speakers to choose a certain pattern in the early stages of language acquisition. Once a pattern is chosen, it could be retained in adulthood a "Peter Pan sound pattern, one that can never grow up and be shared in a language community" (Mielke, Baker & Archangeli 2011: 720).

The results would pose questions about the mechanism governing the mapping between phonetics and phonology, although the whole mechanism of acquisition through potentially many different factors that cause variability is beyond the scope of this research.[67] These issues should be postponed for further research, along with the elaboration of Emergent Grammar (Pulleyblank 2004, 2006a, b, Mielke 2005, 2008, Archangeli, Mohanan & Pulleyblank 2010, Archangeli, Baker & Mielke 2011, Mielke, Baker & Archangeli 2010).

[67] Those factors may include physiological ones. For example, the proportion of the palate and the tongue of children is different from that of adults, which may make the production of velars unique (see Y. Rose (2011), Inkelas & Y. Rose (2008)).

Chapter 5 **Conclusion**

This dissertation has presented multiple case studies of phonetic aspects of allegedly placeless consonants of Japanese, namely the moraic nasal and the glottal fricative. The aim was to assess whether or not those consonants have articulatory targets in intervocalic position, based on ultrasound experiments. The results show that these two kinds of placeless consonants behave differently: Articulatory targets were found in moraic nasals for all speakers, while for the glottal fricative consonant, targets were found in 5 out of 6 speakers.

The implications of this research can be decomposed into empirical, methodological and theoretical contributions. Each will be described below.

5.1. Empirical Contribution

A variety of transcriptions for Japanese /N/ have been recorded in the previous literature. Although previous studies based on ultrasound (Nakajima 2003) and x-ray (Nakano 1969, Uemura & Takada 1990) show images of the oral tract in the production of the sound, they lack quantitative measurements of multiple subjects. Thus, no instrumental report has been made about how much variability exists in the production of /N/ across speakers. Thus, the ultrasound study here, reporting quantitative measurements of 6 native speakers of Tokyo Japanese, is the first instrumental evidence to show that PoA varies from speaker to speaker.

The study of variability is important because phonetic variability plays an important role in the establishment of phonological structure, and provides us with valuable information about the mapping between phonetics and phonology (see sec. 5.2.).

Transcriptions based on auditory impressions may lead us to make errors, because these varieties of PoA are not easily distinguishable auditorily. We know that the auditory impression may not be reliable, since, for example, it is often affected by the level of auditory training or linguistic experience of the transcribers. It is reported that transcribers tend to utilize linguistic knowledge and information about the talkers in order to determine transcriptions when the pronunciation is audibly ambiguous, as in child speech (e.g., Munson, Edwards, Schellinger, Beckman & Meyer 2010). Audibly ambiguous sounds are of course not limited to child speech: In adult speech, a sound can be less clear in coda position relative to onset; less clear in unstressed position than in stressed position; less clear in nasals than in obstruents, and so on.

These factors all contribute to making Japanese /N/ audibly ambiguous. It is also true that clarity depends on speech rate, lexical frequency, and sociolinguistic factors such as age and gender. Whatever factors would be relevant, the auditory transcription alone would not be reliable enough to determine the accuracy of a sound.

The experimental results suggest that the PoA of /N/ varies depending on the speaker, and it encompasses the postalveolar zone up to the pharyngeal zone. The question is whether any other subzone is possible for the PoA of /N/. In Bloch (1946), there is a description of Japanese /N/ as alveolar or velar. Bloch is the only person who says the alveolar subzone may be used for the PoA of Japanese /N/,[68] which could be ascribed to his bias in transcription. But from the point of view that positively admits interspeaker variation, nothing seems to prevent us from coming up with a hypothesis that any subzone is possible. In order to prove this, more subjects would be necessary.

Labial subzone may be another possible target for /N/, and it is true that the labial closure is often seen in word-final position in very slow speech or in songs. But in order to test it, video recording of the lip activity would be desirable. Furthermore, in order to prove that it is a simple labial PoA rather than labial cum dorsum raising, the video recording should be made with an instrument that captures dorsum activity such as ultrasound. It would be interesting if there is a combination of dorsal and labial, because no theory predicts this kind of complex segment should appear as an output of neutralization. It has been assumed that a complex segment itself is assumed to be more marked than a simplex segment (Prince & Smolensky 1993), and labial and dorsal are more marked than coronal (Paradis & Prunet 1991, but see Hume & Tserdanelis 2002, Hume 2003, 2004). Thus the combination of dorsal with labial as an output of neutralization may pose a question about the universal status of the PoA markedness hierarchy. Moreover, if a combined articulation - simultaneous constrictions at two places - appears, the next question would be which of velar or labial would function as the major articulator, and which as the minor articulator (see Clements & Hume 1995: 285). In order to explore this question, the degree of constriction should be examined. The examination could be extended to crosslinguistic /N/,

[68] Aoyama (2003) suggests the underlying form of the Japanese placeless nasal should be /n/ rather than /N/ based on perceptual experiments.

including Polish /N/, whose phonetic realization is assumed to be the labio-velar glide [w̃] (Czaykowska-Higgins 1992).

The ultrasound study conducted here shows that the two kinds of allegedly-placeless segments do not behave in the same way; while /N/ is place-specified for all speakers, /h/ is placeless or place-specified depending on the speaker. What is interesting is that it enabled us to see tongue root retraction in the production of Japanese /h/, which is not clear auditorily. Since the tongue root retraction is visible only in physical signals, the degree of retraction is considered to be relatively small. Although the retraction is relatively inaudible in Japanese, the finding is not trivial, because the data suggests that speakers of the same dialect are divided into retractors and non-retractors. The fine-grained phonetic distinction of this kind may be labeled as what Ohala (2011: 55-6) calls the "secondary distinctive features" that may become primary if listeners misinterpret them (Ohala 1981, 1993). And such features give an important clue to potential change, because sound changes typically start with low-level phonetic changes (Hansson 2008, Kiparsky 1995, Hyman 2008).

What feature should be posited for the tongue root activity is a separate question. Features such as laryngeal, RTR, TR, Radical, etc. could be posited depending on the feature geometry model (McCarthy 1994, Cole 1987, Shahin 2002, Howe 2004, Halle, Vaux & Wolfe 2000 etc.). But many other analyses are also possible and worth exploring. For example, the tongue root retraction in /h/ and dorsum raising in /N/ that we observed could be actually a side effect of some other featural event which is unnoticeable and something invisible even in the ultrasound, but only visible by other methods. Francis, Klenin, Mizrahi, Tom & Gick (2011), based on the analysis of x-ray videos of the articulation of Canadian French uvular /ʁ/, proposes that uvular and velar constrictions are actions of the *palatoglossal sphincter*, not just made by the raising of the tongue. The active movement of the palatoglossus is also visible in EMG (Bell-Berti 1976) and MRI (Takano & Honda 2007). These studies suggest that any hidden feature could be active in combination with other features, or could be independently activated even if nothing is visible on the tongue. For future research, we could combine ultrasound with other instruments so that what features can be independent, and how various features can interact with each other, can be determined. However I believe that it is important to make the inaudible data visible and measurable with appropriate procedures as a first step.

5.2. Theoretical Contribution

Chapter 2 examines whether the moraic nasal of Japanese has an articulatory target, and shows that every speaker has a specific target. Chapter 3 tests the pharyngeal /h/ hypothesis, and we found that a subset of speakers have a target in the pharyngeal area. Chapter 4 tries to detect where the target of /N/ is for all speakers, and found the location target is idiosyncratic, ranging from postalveolar to uvular.

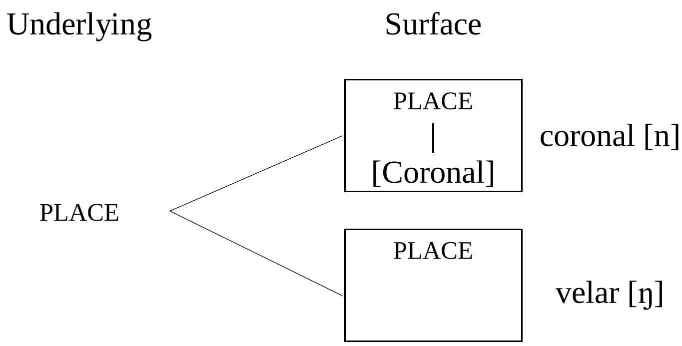
5.2.1. Permanent Underspecification Hypothesis

It has been questioned whether or not there are segments that have no phonetic target. Keating (1996: 273) states, "Phonetic underspecification means that not every segment has to have a specification, or target, for every feature/gesture." The experimental results in this thesis in general do not support the permanent underspecification hypothesis. The findings here are that /N/ has a target for all speakers, and /h/ has a target for 5 out of 6 speakers. So a potentially permanent placelessness would be restricted to one speaker for /h/ only.

In the framework that I adopted in this dissertation, there is no distinction between 'temporary' and 'permanent' underspecification, although such a distinction exists in the derivational framework of the 1980s -1990s. In the derivational rule-system, an 'unmarked' or 'predictable' place is assumed to be unspecified underlyingly, and the surface place, which is, in the majority view, Coronal, is realized through the application of a default fill-in rule (e.g., Paradis & Prunet 1991). This is a case for temporary underspecification. But if such a rule is not operative, the underlyingly placeless segment is expected to remain unspecified for place at the surface. This is a case for a permanently underspecified segment, which is in the majority view, laryngeal segments (e.g., Steriade 1995).

This dichotomy is somewhat challenged by a view that dorsals rather than coronals can be unmarked (Trigo 1988, Harris 1990). In order to reconcile the two opposite views – coronal vs. dorsal as unmarked place – Rice (1996) proposes Default Variability Hypothesis, presenting a model that can derive either coronal or dorsal as a default. The default variability is supported by crosslinguistic phonological patternings such as assimilation, distribution and epenthesis (Rice 1996: 494-6), as well as the phonetic correlates of /N/ - for Japanese /N/, the tongue position is neutral with respect to the articulatory setting (see Vance 1987: 35ff.). In Rice's model, the dichotomy of coronal vs. laryngeal seems to shift to the dichotomy of coronal vs. velar, as illustrated below.

(5.1) Two Unmarked Places in Rice (1996)



This illustration shows that both coronal and velar are derived from one underlyingly placeless representation. At the underlying level, there is a single representation that has a bare node PLACE without any dependent feature. Then the derivation has two choices: If the default insertion applies, it would become coronal [n], while if the rule fails to apply, it remains unspecified in the surface phonology. It is possible to think that the latter case is permanent placelessness, in the sense that placelesness persists throughout the phonology.

But it is not permanently placeless in a strict sense, because Rice assumes a mechanism of "phonetic interpretation" which interprets the bare place node as velar. Thus, when we look at the phonology-phonetics interface, [ŋ] is no longer permanently placeless. This is clarified below.

(5.2) Three Types of Placelessness in a Derivational Framework

	phonology		phonetics
	underlying	surface	surface
[n]	placeless	Coronal	Coronal
[ŋ]	placeless	placeless	Velar
[h]	placeless	placeless	placeless

The coronal nasal is underlyingly placeless, and the glottal fricative is permanently placeless at any level of phonology and phonetics. The velar nasal is positioned between them, in that it is phonologically placeless but not phonetically placeless.

The conversion of placelessness to velar is also postulated in Trigo (1988: ch.2), but in a slightly different way. Trigo argues that the phonological rule that inserts dorsals applies to placeless consonants generally, not just /N/. In other words, allegedly placeless glides such as [N] and [h] are [-consonantal] in the inventory, and are/can be converted to [+consonantal][69] at a later stage. Thus, the categorical status of /N, h/ on the surface does not have to match with their categorical status in the phonetics. It is not clear whether the later conversion to a consonant is obligatory or optional, and why such a mismatch has to be postulated.

In the framework of OT, how phonology interacts with phonetic interpretation is different depending on the version of the theory.[70] But in the current PoA markedness hierarchy, there is only one least marked place – either coronal (Prince & Smolensky 1993), pharyngeal (Lombardi 1991) or glottal (de Lacy 2006) – and it predicts that the output of neutralization should be the same for all speakers of the same dialect. de Lacy's (2007) version states that the optimal candidate should be appropriately interpreted in the phonetic component. Thus if glottal /N/ is a winner in phonology, then it will be converted to velar-uvular in the post-phonological component.

The question that we should pose to the theories above is how they treat individual variation. For example, if /N/ is placeless (Rice 1996) or non-placeless glottal (de Lacy 2006, 2007) in the output, and if it has to be uniform across speakers, then it has to be in the phonetic interpretation where we can deal with individual variations. In other words, the mapping between phonetics and phonology needs to be flexible, not automatic and universal. In consequence, this system needs to postulate another mechanism to allow a non-placeless glottal to convert multiple places such as post-alveolar, velar and uvular, for example.

In my mapping model (sec. 1.1.4. in p.171.1.4. Mapping Relations), such a mismatch and the repair mechanism or any stipulatory phonetic interpretations are not posited. Ranked constraints choose an optimal output from any input, thus the winner should be seen in the output

[69] In Trigo's definition, the glides [N, h, ʔ] are [-consonantal], and [ŋ, x, k] are [+consonantal].
[70] The UCLA tradition in OT explores how perceptual/articulatory difficulty directly maps onto phonological constraints. See Hayes, Kirchner & Steriade (2004).

of phonology. But what remains to be done is determine how individual variations are embodied in phonology. In order to capture the multiple outputs in OT, we need to allow variant constraint rankings depending on the speaker. The point that should be made is the least marked place needs to be variable with some restriction, so that multiple places can be available for speakers' choices.

In the framework of the direct mapping between phonology and phonetics outlined in chapter 1, the choice of the feature specification must be embodied in both phonetics and phonology, because the featural specification and the physical signal correspond to each other and they cannot be disconnected. In other words, the idiolectal difference should be treated in the phonology-phonetics mapping.

5.2.2. Contrast in Pharyngeal Class and Inventory-Driven Place-Specification of /h/

Based on the experimental result, I conclude that /N/ can be categorized as dorsal (if it is velar, palatal and postalveolar), and as pharyngeal (if it is post-velar), depending on the speaker (see sec 4.3.2.3.2.). The results do not support an inventory-driven hypothesis (Rose 1996), since we unexpectedly found the speakers having Dor /N/ - AM, HS, YS and KK – also having Phar /h/. The summary is given below.

(5.3) Summary of Place of /N/ and /h/

	N	/h/
AM	velar [ŋ˔]	pharyngeal [ħ]
HS	velar [ŋ˔]	uvular [χ]
TT	postalveolar [n˔]	uvular [χ]
YS	velar [ŋ˔] ～ palatal [ɲ˔]	pharyngeal [ħ]
KK	velar [ŋ˔] ～ palatal [ɲ˔]	placeless [h] or dorsal [x]
MK	uvular [ɴ˔]	uvular [χ]

Oral Guttural (post-velar)

This conclusion is reached under the assumption that velar and pre-velar /N/ are *not* Pharyngeal while post-velar /N/ is Pharyngeal.

However, if Japanese /N/, regardless of the individual variations, is categorized as a phonologically non-placeless glottal (de Lacy 2006), then /N/ and /h/ would be contrastive in the phonologically-defined glottal category, and the conclusion would turn out to be in favor of Rose's hypothesis. There are at least two arguments that they are contrastive in glottal.

Firstly, de Lacy (2006: 37-42) argues, in his formal theory of markedness, that the phonologically 'glottal' class includes not only glottal stop [ʔ] and glottal fricatives [h ɦ], but also the 'placeless nasal glide' (nasalized glottal continuant/voiced glottal approximant) [ɦ̃] and the 'glottal nasal stop' [N]. Below, the two segments are added to the current IPA chart.

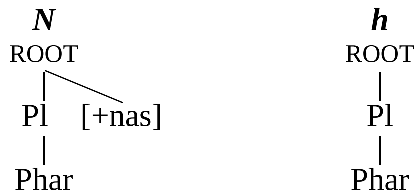
(5.4) Segments in Glottal Column

	glottal	
plosive	ʔ	
nasal		N
fricative	h	ɦ
approximant		ɦ̃

In the current IPA chart, voiced plosive, the row of glottal nasal, and the row of glottal approximant are shaded, denoting articulations judged impossible. But Walker & Pullum (1999: 767) state that glottal (and pharyngeal) nasals are phonetically possible, stating "There is no articulatory difficulty associated with lowering the velum during a glottal stop, nor for that matter during a pharyngeal or epiglottal one", and suggest [ʔ̃] and [ħ̃] are permissible phonetically and phonologically. Evidence comes from a phonemic contrast between nasalized glottal vs. oral glottal and the eligibility to trigger nasal harmony, attested in African, Amazonian, and Austronesian languages.

Since Japanese /N/ could be pronounced with or without oral closure, the contrast of [N] vs. [h] or [ɦ̃] vs. [h] should exist. Ignoring the distinction of continuancy, if I interpret de Lacy's ‘non-placeless glottal’ as equivalent to pharyngeal, then the contrast between [N, ɦ̃] vs. [h] could be represented as below. [71]

(5.5) Possible Contrast between /N/ vs. /h/



The second argument for the contrast is the crosslinguistic phonological patterning of /N/. Neutralization, debuccalization and epenthesis prefer glottals, which would follow from the ranking scale of PoA markedness: dorsal > labial > coronal > glottal (> means ‘is more marked than’) (de Lacy 2006, Lombardi 2001).

If the velar nasal attested in my experiment is categorized into the Pharyngeal class, then 4 out of 6 speakers fit to the prediction of Rose. Unpredicted patterns would be TT having Pharyngeal [χ] with Oral nasal [n], and KK having placeless [h] with Pharyngeal nasal [ŋ].

5.2.3. Universality of PoA Hierarchy

Emergent OT (Archangeli, Mohanan & Pulleyblank 2010, Pulleyblank 2003, 2004, Mielke 2008, Kim & Pulleyblank 2009, Mielke, Baker & Archangeli 2010) claims that features

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[71] One may argue that Pharyngeal node does not have to be introduced, since these segments are contrastive in [nasal, voice]. But the ambiguous nature of [voice] and [continuant] in guttural segments is pointed out. Rose (1996: 80) implies that these features can be ignored for contrast of gutturals:

> Contrasts are established, and the NAC is operative, within a particular class of segments, i.e. among non-continuants or among continuants. However, the guttural region is special in that continuancy is not contrastive among pharyngeals, and voicing is not contrastive among laryngeals (both laryngeals lack a [voice] specification). Manner features such as [continuant] or [voice] do not serve to contrast pharyngeals and laryngeals in the same manner as they do the other segments, and, ignoring other minor phonetic differences, place specifications are the best means to distinguish between segments in the guttural region. Therefore, the mere presence of a primary Pharyngeal place node will be enough to force specification of laryngeals as Pharyngeal.

Contrasts of this type can be pursued from various aspects of phonology – dispersion theory (Flemming 2001, Ní Chiosáin & Padgett 2001), and how the concept of contrast plays roles in theory, perception and acquisition (Avery, Dresher & Rice 2008). The typology of glides (Nevins & Chitoran 2008, Padgett 2008) is also a relevant issue.

and constraints are emergent properties rather than innate, predicts multiple instantiations of features, and explains different phonological behaviours crosslinguistically. Thus, constraint ranking is not universal either, so markedness reversal is also expected.

This theory makes a sharp contrast with the universalist position. The basic tenet of early Generative Phonology (SPE) was that the featural realization at phonetics is automatic and universal. What is meant here by automatic and universal is one-to-one mapping between features and phonetic implementation and they are the same crosslinguistically. The same stance is recently kept in Hale, Kissock and Reiss (2007).

In de Lacy's theory, the neutralized PoA should be either glottal or coronal, and velar or labial should never appear. Markedness reversal should not happen because the PoA hierarchy is assumed to be 'context-free' and consistent regardless of syllable position.

De Lacy (2002: 49-51) proposes that non-segmental properties such as sonority and tone must combine with structural positions such as stress-prominence position to derive a hierarchy combining with structural positions, but subsegmental properties such as voice, nasal and PoA should never combine with structural positions. But so far no strong argument seems to be against a 'context-sensitive' PoA markedness hierarchy.

It is true that it has been established in early OT that prosodic elements such as sonority combines with structural positions. For example, "Peak hierarchy" *P/t » … » *P/l, » » *P/a and "Margin hierarchy" *M/a » *M/i » *M/l » … » *M/t (Prince & Smolensky 2004: 167) illustrate that sonority markedness is reversed depending on the peak and margin. de Lacy's (2002) idea of combining tone hierarchy *H » *M » *L with stressed/unstressed position is in the same line. But Pulleyblank (2004) states that there seem to be purely tonal cases that do not necessarily have to refer to any structural position, and shows that in Yoruba, the least marked tone is M rather than L, meaning that the appropriate hierarchy is *H » *L » *M. Furthermore, it seems some segmental features prefer to appear in certain structural positions. A well-known case is coda devoicing, where the voice distinction is neutralized to [-voice] in Russian, German, and Turkish. Dorsal also prefers to appear in rhymal position (Harris 1990, Kaye, Lowestamm & Vergnaud 1990, Bernhardt & Stemberger 1998). Finally, the PoA markedness hierarchy could vary if combined with manner features. In coda position in Japanese, velar looks unmarked for nasals, but for stops, coronal looks unmarked: Itô & Mester (1996) argues that [t] is underspecified but [k] is specified, in order to explain why /t/ undergoes contraction but /k/ does not (e.g, bet-kaku → bekkaku, *betu-kaku, 'separate class' vs. hak-choo → haku-choo, *hattyoo 'swan'). So the markedness hierachy could be different, depending on whether it combines with structural position, or on other factors such as manner features. Rice (2003) argues that the universal markedness claim is too strong, and markedness may vary depending on the structural position.

In this section, I have posed a question as to the universality of PoA hierarchy. The results suggest that the unmarked PoA may not be uniform across speakers of Tokyo Japanese. It is pointed out that the constraints, hierarchy, and features may be emergent rather than innate, where the mapping of phonetics to phonology should be considered as a learning model. The same direction is explored in Boersma's bidirectional phonology and phonetics model (2007, 2009), where the connection between the phonological structure and implementation is learned and language-specific (see Hamann, Nasukawa, Kula & Botma 2011 for a review).

5.3. Methodological Contribution

Although the Target-Interpolation model (Cohn 1990, 1993) has never been tested in terms of ultrasound imagings, I have developed a methodology that can test the hypothesis.

The articulatory data in previous research lack quantiative measurements and/or are limited to a single subject, but this thesis presented measurements of six speakers.

Problems about the compatibility between Edgetrak and SS-ANOVA were resolved (see sec. 2.2.3.4. in p. 70ff for the details).

5.4. Limitations

A number of caveats need to be noted regarding the present study. The most important limitation lies in the fact that the experiment was conducted by ultrasound equipment only, which does not allow us to see other areas such as the lip and pharyngeal area directly. The relation of lip gestures to /h/ in Japanese has been recognized in the literature, which suggests that it historically shifted from /p/ (see Yamaguchi 1997, Shibatani 1990: 166-7 for details). Synchronic data also suggests alternations of /p-h/, for example, in rendaku (e.g. /hana/ 'flower' but /ikebana/ 'living flower') (Otsu 1980, Itô & Mester 2003, Fukazawa & Kitahara 2001, Rosen

2003, Takayama 2005). It would be interesting to explore the phonetic relation of lip activity to the historical development of /h/ (e.g., Foulkes 1997), but this topic is beyond the scope of this thesis.

For the purpose of viewing the pharyngeal activity, which is my main interest, x-ray (Gick 2002, Uemura & Takada 1990) or MRI (e.g., Gick, Kang & Whalen 2002, Zhu & Hatano 2010) may be more suitable than ultrasound, so it is a challenge for me to argue about pharyngeal specifications solely based on the tongue root retraction which is visible on the ultrasound images. In fact, researchers have reported that the activity of the pharynx itself is complex in direction and degree of expansion (cf. Elgendy 2001, Lindau 1979, Tiede 1996), and multiple sphincters close to the larynx may be responsible for pharygeal activity (Esling 2002, 2005), thus a phonological feature pertaining to guttural may be replaced by these sphincter features (Gick 2011). Still it is worth using ultrasound because it is safe, economical and easily accessible (see Gick 2002, Gick, Bird & Wilson 2005, Wilson 2006).

It has also been recognized that the tongue may be influenced by movement of a non-lingual organ such as the larynx. Nakajima (2003) demonstrates that movement of the larynx is detectable using M-mode [72] in ultrasound. But my recorded data is restricted to B-mode [73] so it is not detectable. Therefore the effect of larynx raising on the tongue, concomitant with the shift of pitch and voice, must be left for further research.

5.5. Further Research

What Trigo (1988) calls the placeless nasal glide /N/ exists across languages, and phonological similarities of patterning of /N/ between Japanese and other languages have also been suggested (Trigo 1988, Flynn 2004, Akinlabi 2007). But crosslinguistic experiments of this sound seem to be scarce (but see Ramsammy (2010) for an acoustic study of Spanish coda nasals). Also, I limited the study here to standard Tokyo Japanese, but it would be interesting to develop contrastive studies of Tokyo Japanese and other dialects such as the Osaka dialect (Tronnier 1996, 1998), the Kagoshima dialect (Haraguchi 1984, Kaneko & Kawahara 2002) and

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[72] "M-mode stands for 'motion mode'. It captures returning echoes in only one line of the B-mode image but displays them over a time axis. Movement of structures positioned in that line can now be visualized." (http://www.sonoguide.com/physics.html)

[73] "B-mode stands for 'brightness mode' and provides structural information utilizing different shades of gray (or different 'brightness') in a two-dimensional image" (http://www.sonoguide.com/physics.html)

the Okinawan dialects (Shimabukuro 1997), where morphophonemic alternation involving /N/ seems to be more extensive. Another question is what phonological grammar is. Early generative grammar assumed that there is an ideal speaker-hearer, and that a person's grammar should reflect the knowledge that is shared in the speech community. From the point of view of generative phonetics (Pierrhumbert 1980 and others), which branched from generative phonology, there should be a one-to-one mapping system between phonological units and physical signals, and this mapping should in principle be the same across all speakers of the same language or the same dialect. But there do exist idiolectal differences anywhere – in syntax, morphology, semantics, phonology. And the differences should reflect sociolinguistic factors such as age, gender, cultural backgrounds. As idiolects exist in each domain, it should exist in interfaces such as the phonology-to-phonetics mapping.

Variation is not a main concern for early generative phonologists, as it was assumed to be an issue of the performance level. But after the 1990's, the study of variation has received more attention in formal theories such as OT. Efforts have been made to explain that the observed variation is not random, but follows typological predictions. The similarities between synchronic variation and diachronic change, and between interspeaker variation and intraspeaker variation, have also been captured with the interaction of markedness and faithfulness constraints. Antilla & Cho (1998) demonstrate in OT that typological universals emerge statistically within an idiolect. How these variations should be modelled is another theoretical issue (Nagy & Reynolds 1997, Antilla & Cho 1998, Coetzee & Pater 2011).

What is now needed is a cross-linguistic study involving the fine-grained details of the articulation of /h/ and /N/. Cohn (2011: 14-5) says,

> As phonologists, we need to take seriously the evidence of the effects of fine-grained details on phonology. Yet on the other side, this does not mean that there is not true abstraction. It is important to realize that just because abstract knowledge may be built out of fine-grained details (one of the ideas within the notion that language is emergent), it does not mean that the abstractions do not exist.

A "sound" such as [h] may be the product of abstraction, and the same sound can be interpreted in different ways phonologically (e.g. Archangeli & Pulleyblank 1994). Furthermore, even if the same "feature" is used, the precise phonetic property of a phonological feature may be different from language to language (Pulleyblank 2006a, b, 2011, Archangeli, Baker & Mielke 2011, Mielke 2008). If we follow this logic, more than one way of implementation is expected for the same feature crosslinguistically.

The asymmetrical patterning of the same segment /h/ - pharyngeal /h/ (McCarthy 1991, 1994) vs. placeless /h/ (Steriade 1987a) - has been attested across languages. Cooccurrence restrictions and vowel lowering are typical arguments for pharyngeal /h/, and I argued that Japanese /h/ is also pharyngeal, by presenting the view of cooccurrence restriction to ban *hi and the results of an experiment showing pharyngeal constriction.

Similarly, it is expected that the seemingly same /N/ or anusvara (Trigo 1988) may pattern differently depending on the languages. The following patterns are what de Lacy (2006: 39-42) raised as evidence for a glottal place for /N/.

(5.6) Evidence for glottal nasal

a. Coda nasals become [N], as coda stops become [ʔ] in Kagoshima Japanese
b. [N] is epenthesized in word-final words in Uradhi
c. Nasal stops become [N] before /h, ʔ/, as oral stops become [ʔ] before /h/ in Yamphu
d. [N] retracts the preceding vowel to RTR in Miogliola
e. [N] is banned in onset position in Briat and Miogliola
f. [N] alternates with [ɦ̃] in Aguaruna

/N/ in different languages patterns somewhat differently; characteristics except (e, f) have not been claimed for /N/ of Tokyo Japanese. Even among dialects of Japanese, the segment inventory, phonotactics, and debuccalization patterns are diverse. The Okinawa dialects of Japanese, which are known to have similar neutralization patterns to those of Kagoshima Japanese as in (a), show some uniqueness: (i) /N/ appears in verbal conjugations regularly as the conclusive form (e.g., [sur<u>u</u>] $^{\text{TJ}}$ - [su<u>N</u>] $^{\text{NOJ}}$ ‘do’, [jom<u>u</u>] $^{\text{TJ}}$ - [ʼjum<u>iN</u>] $^{\text{NOJ}}$ ‘read’ (Shimabukuro 1997: 366)), (ii) /N/ can appear after /ʔ/ or /ʼ/ (non-glottalized phoneme) in word-initial position (e.g., [ʼNni] /mune/ ‘breast’, [ʔNmu] /satsuma-imo/ ‘sweet potato’), (iii) long /N/ exists (e.g., [ʼN:zuN] /miru/ ‘see’ (Examples from Uemura (1997b: 332)). These are not seen in Kagoshima or Tokyo Japanese. Furthermore, Ghini (2001) shows Miogliola /N/ is usually non-moraic but becomes moraic before a consonant or after a stressed vowel, but the /N/ of Tokyo Japanese is always moraic. Akinlabi (2007) observes /N/ in Yoruba, showing nasal place assimilation applies everywhere, i.e., within words or phrases, but before a vowel or [h], the nasal is velar. The across-the-board application of nasal place assimilation is also widely assumed for Tokyo Japanese, but how /N/ before [h] is realized will not be clear without instrumental experiments. Nonetheless, de Lacy (2006: 142-3) states that what has been claimed as a “velar” nasal in Huallaga Quechua, Seri, Yamphu, Selayarese, Makassarese, Misantla Totonac (San Marcos Atesquilapan dialect), Spanish dialects, and the Carib languages Arekuna, Tiriyó, and Wayana, is actually glottal. But in my view, phonetic evidence may reveal that the realizations of /N/ are not uniform depending on the language.

The concept of distinctive features has led researchers to find phonemes and allophones, and develop phonological rules and constraints. A finite and relatively small set of features (e.g., SPE type features) should be able to represent every possible linguistic sound. However, it has been noticed that there seems to be limitations to represent the unique characters of the segment: We know that [i] in Japanese, for example, is a slightly different sound from [i] in Canadian English. So the question is how we capture such phonetic knowledge. In the earlier framework where there is a split between phonology and phonetics, “language-specific phonetic” rules are added after the phonological representations, and derive the uniqueness of the sounds. But it should be true that if distinctive features are more diverse than what has been proposed so far, then we may be able to capture the uniqueness of the sounds with the augmented set of distinctive features, without using language-specific phonetics.

This was shown in chapter 3, where unspecified features could have two different types – an interpolation type and an assimilation type. Further work needs to be done to establish what model should be appropriate. But as suggested in chapter 4, if the attested variations are idiosyncratic ‘Peter Pan sound patterns’, then the model should ideally explain how children learn rankings of constraints (Archangeli, Mohanan & Pulleyblank 2010, Pulleyblank & Turkel 2000, Hansson 2008, Blevins 2004, Tanaka 2011, Munson, Edwards, Schellinger, Beckman & Meyer 2010, etc.).

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Appendices

A. Reading List

The word list that participants read during the experiment consisted of 4 pieces of paper, as shown in Tables A.1. - A.4. The list is included here to show that i) the set of 55 nonce words was randomized, ii) 14 blocks of the same set with different orders were created, and iii) the list was printed in katakana letters.

Table A. 1. Page 1 of reading list

第1セット				第2セット				第3セット				第4セット			
1	アンヘ	29	オン	1	インオ	29	イッキ	1	ウンヘ	29	インオ	1	イッカ	29	アッキ
2	インア	30	インイ	2	エン	30	イッホ	2	イッヒ	30	アンハ	2	インキ	30	アンホ
3	インコ	31	エン	3	アッカ	31	イッケ	3	アン	31	インカ	3	アッヘ	31	ウッケ
4	アンコ	32	インキ	4	イッヘ	32	アンハ	4	ウッヘ	32	アンエ	4	イッヒ	32	ウンエ
5	アンカ	33	アンア	5	ウンエ	33	アッハ	5	エン	33	イッコ	5	アンイ	33	オン
6	アン	34	イッヒ	6	アンヘ	34	ウッホ	6	インヒ	34	ウンコ	6	インホ	34	エン
7	イッハ	35	ウッケ	7	アンキ	35	アッキ	7	アッヒ	35	ウンホ	7	アンハ	35	イン
8	ウンケ	36	ウン	8	イッハ	36	イッヒ	8	アッコ	36	イッカ	8	アンオ	36	ウンヘ
9	イン	37	アッカ	9	イッコ	37	アッケ	9	インコ	37	インイ	9	アンエ	37	ウンケ
10	インヘ	38	インエ	10	ウン	38	ウンオ	10	アッホ	38	アッカ	10	イッハ	38	イッコ
11	アッハ	39	ウンホ	11	アン	39	アンカ	11	アッキ	39	アンカ	11	イッキ	39	インオ
12	インヒ	40	ウンエ	12	アンケ	40	インカ	12	アンオ	40	イッケ	12	アンケ	40	アンカ
13	アンキ	41	イッヘ	13	アンヒ	41	アンエ	13	インキ	41	インハ	13	アッカ	41	アッヒ
14	アッキ	42	イッキ	14	イン	42	ウンヘ	14	アンホ	42	ウンオ	14	ウッヘ	42	アッホ
15	アンヒ	43	アッヘ	15	アンイ	43	アッヒ	15	アンヘ	43	アンア	15	インハ	43	インカ
16	ウンコ	44	ウンオ	16	オン	44	アッホ	16	ウッホ	44	アンヒ	16	アンヘ	44	アンコ
17	アッホ	45	イッホ	17	インホ	45	インエ	17	インア	45	アッヘ	17	アッケ	45	アッコ
18	イッケ	46	アンケ	18	インコ	46	ウンコ	18	ウンエ	46	イン	18	インヒ	46	インイ
19	イッカ	47	インハ	19	インハ	47	アンホ	19	アンキ	47	アンケ	19	インケ	47	アン
20	アンハ	48	インケ	20	インイ	48	アッコ	20	イッホ	48	ウッケ	20	ウンオ	48	イッホ
21	アッケ	49	アッヒ	21	インア	49	ウッケ	21	アンコ	49	ウンケ	21	アンキ	49	ウンコ
22	ウッホ	50	アンオ	22	ウンケ	50	アンコ	22	ウッコ	50	インヘ	22	インエ	50	ウッコ
23	ウンヘ	51	アンイ	23	ウッコ	51	ウッヘ	23	インホ	51	アッケ	23	インコ	51	イッヘ
24	インオ	52	アンエ	24	インヒ	52	インケ	24	インエ	52	ウン	24	イッケ	52	インア
25	アンホ	53	アッコ	25	インキ	53	インヘ	25	イッキ	53	アッハ	25	インヘ	53	ウン
26	イッコ	54	インホ	26	イッカ	54	ウンホ	26	イッヘ	54	インケ	26	アンヒ	54	アンア
27	ウッコ	55	ウッヘ	27	アンア	55	アンオ	27	イッハ	55	アンイ	27	ウッホ	55	ウンホ
28	インカ			28	アッヘ			28	オン			28	アッハ		

Table A. 2. Page 2 of reading list

第9セット				第10セット				第11セット				第12セット			
1	インコ	29	アンヘ	1	インキ	29	アン	1	ウンケ	29	イッハ	1	アッヒ	29	アンコ
2	インオ	30	アッキ	2	アンキ	30	アンケ	2	インホ	30	アンホ	2	インカ	30	アッキ
3	アッヒ	31	インケ	3	アンカ	31	アッヘ	3	アッヒ	31	ウッケ	3	インオ	31	アッカ
4	イッホ	32	ウンエ	4	イッヘ	32	アンエ	4	インハ	32	インコ	4	インヘ	32	インケ
5	アンケ	33	アンイ	5	ウッケ	33	ウッホ	5	アンオ	33	インエ	5	インホ	33	アンホ
6	アンオ	34	インエ	6	イン	34	ウンオ	6	インヘ	34	アンカ	6	アッヘ	34	インキ
7	アッコ	35	インホ	7	アンア	35	インホ	7	イッヘ	35	インキ	7	イッホ	35	ウンオ
8	アッヘ	36	アンカ	8	インエ	36	イッハ	8	アンコ	36	イッケ	8	イッヘ	36	ウッホ
9	イッヒ	37	イッキ	9	インハ	37	アッキ	9	アンキ	37	イッヒ	9	イン	37	インハ
10	アン	38	インカ	10	イッキ	38	アッヒ	10	アンエ	38	ウン	10	ウンホ	38	イッヒ
11	インヘ	39	エン	11	インケ	39	アンオ	11	ウンヘ	39	イン	11	アッコ	39	アッハ
12	アンハ	40	アンア	12	アッケ	40	イッカ	12	イッコ	40	アンハ	12	ウンコ	40	イッコ
13	アンコ	41	アッケ	13	エン	41	イッヒ	13	アッキ	41	インオ	13	ウッヘ	41	インイ
14	アッホ	42	ウンケ	14	オン	42	ウッコ	14	アンケ	42	アッハ	14	ウン	42	アンカ
15	ウンヘ	43	ウッコ	15	アッカ	43	アンコ	15	ウンコ	43	アンイ	15	アンヒ	43	アンケ
16	イン	44	インキ	16	ウン	44	アッホ	16	アンヒ	44	ウンエ	16	エン	44	ウッケ
17	アッカ	45	イッコ	17	ウンホ	45	インカ	17	アッケ	45	イッホ	17	アンハ	45	アンア
18	イッハ	46	アンホ	18	インオ	46	アンハ	18	ウッホ	46	イッキ	18	イッハ	46	アッホ
19	インヒ	47	アッハ	19	ウンコ	47	アッハ	19	ウンオ	47	アッコ	19	アッケ	47	イッカ
20	オン	48	アンキ	20	アッコ	48	インコ	20	アン	48	オン	20	アンオ	48	アンヘ
21	イッケ	49	イッヘ	21	ウンヘ	49	イッホ	21	ウッヘ	49	ウンホ	21	ウンヘ	49	ウッコ
22	ウンオ	50	ウッヘ	22	インヘ	50	イッケ	22	イッカ	50	インケ	22	イッキ	50	オン
23	インイ	51	ウッケ	23	インイ	51	インア	23	ウッコ	51	エン	23	インア	51	インコ
24	ウン	52	イッカ	24	ウッヘ	52	アンホ	24	アッホ	52	インア	24	ウンケ	52	アンエ
25	ウンホ	53	アンエ	25	アンヒ	53	インヒ	25	アンア	53	アッカ	25	アン	53	インヒ
26	インハ	54	ウンコ	26	イッコ	54	ウンケ	26	インヒ	54	インカ	26	アンイ	54	イッケ
27	インア	55	アンヒ	27	アンイ	55	ウンエ	27	アッヘ	55	インイ	27	インエ	55	アンキ
28	ウッホ			28	アンヘ			28	アンヘ			28	ウンエ		

Table A. 3. Page 3 of reading list

第5セット				第6セット				第7セット				第8セット			
1	インホ	29	アンハ	1	アンキ	29	アン	1	アンカ	29	インホ	1	イッホ	29	インハ
2	アンイ	30	ウンホ	2	ウン	30	インキ	2	ウンホ	30	イッキ	2	インケ	30	インホ
3	インコ	31	エン	3	アッケ	31	アンホ	3	アッホ	31	ウンヘ	3	イッヘ	31	アッキ
4	ウンコ	32	インキ	4	イッケ	32	エン	4	インキ	32	アッヒ	4	アッケ	32	イッケ
5	インイ	33	ウンケ	5	オン	33	イッヒ	5	インオ	33	インエ	5	インア	33	インキ
6	アッキ	34	アン	6	ウンオ	34	アッハ	6	イッホ	34	アンハ	6	アンオ	34	アン
7	ウンオ	35	アッハ	7	インイ	35	インア	7	インイ	35	ウッケ	7	アッヒ	35	アンホ
8	イッケ	36	アンオ	8	イッカ	36	ウンホ	8	イッハ	36	インヘ	8	ウッホ	36	ウッコ
9	アンヒ	37	アッヒ	9	イッヘ	37	イン	9	イッケ	37	ウンケ	9	インカ	37	アンア
10	インオ	38	アッケ	10	アンヒ	38	インエ	10	オン	38	ウンエ	10	インエ	38	ウンオ
11	イン	39	インヒ	11	アンイ	39	アッキ	11	アンヒ	39	アン	11	インイ	39	アンケ
12	インア	40	インヘ	12	イッハ	40	インヘ	12	ウッコ	40	インハ	12	ウンケ	40	アンイ
13	ウンエ	41	アンキ	13	インカ	41	インケ	13	ウンオ	41	アンホ	13	アンヘ	41	イッヒ
14	イッハ	42	ウンヘ	14	インハ	42	ウンヘ	14	インコ	42	アッケ	14	インヘ	42	ウッケ
15	イッコ	43	アッヘ	15	アッカ	43	アッヘ	15	アンキ	43	ウッヘ	15	イッコ	43	ウンヘ
16	アンコ	44	アンエ	16	アンオ	44	インオ	16	インヒ	44	アッキ	16	ウンホ	44	アンコ
17	インエ	45	イッヒ	17	ウンケ	45	インヒ	17	アンイ	45	アッカ	17	インヒ	45	イッキ
18	アンホ	46	ウッヘ	18	イッコ	46	インホ	18	ウッホ	46	アンエ	18	アンハ	46	エン
19	アンヘ	47	アッカ	19	ウンエ	47	インコ	19	イッカ	47	イッヘ	19	アッカ	47	アンエ
20	インケ	48	イッホ	20	ウッケ	48	イッキ	20	アッヘ	48	アンア	20	アッハ	48	アンカ
21	ウッコ	49	インカ	21	アンヘ	49	ウッホ	21	アンオ	49	アッコ	21	オン	49	ウッヘ
22	ウッケ	50	イッキ	22	アンエ	50	アンコ	22	イッコ	50	アンコ	22	イン	50	アッコ
23	アンカ	51	イッカ	23	アッヒ	51	アンア	23	インカ	51	アンケ	23	イッカ	51	アンキ
24	アンケ	52	アンア	24	アンカ	52	アッホ	24	ウン	52	エン	24	インオ	52	アッホ
25	アッコ	53	アッホ	25	ウッヘ	53	アンケ	25	ウンコ	53	イッヒ	25	ウン	53	ウンエ
26	イッヘ	54	ウン	26	イッホ	54	アンハ	26	アッハ	54	アンヘ	26	アッヘ	54	ウンコ
27	インハ	55	ウッホ	27	ウンコ	55	アッコ	27	インア	55	インケ	27	アンヒ	55	イッハ
28	オン			28	ウッコ			28	イン			28	インコ		

Table A. 4. Page 4 of reading list

第13セット				第14セット			
1	イッホ	29	ウッケ	1	アンア	29	エン
2	インハ	30	インア	2	アッハ	30	インオ
3	イッカ	31	アッヒ	3	インコ	31	インハ
4	アンカ	32	イッヒ	4	ウンオ	32	アッヒ
5	イッケ	33	インエ	5	アンハ	33	インキ
6	インホ	34	ウッホ	6	アッケ	34	アッヘ
7	インコ	35	イッヘ	7	ウンケ	35	アッキ
8	アンヘ	36	ウンコ	8	イン	36	アンキ
9	アンエ	37	インカ	9	ウンコ	37	アンコ
10	アッハ	38	アンケ	10	インホ	38	イッコ
11	アッヘ	39	アッケ	11	イッヘ	39	ウッホ
12	アッキ	40	オン	12	ウンホ	40	インイ
13	アンコ	41	アンキ	13	アンオ	41	インヒ
14	ウンケ	42	インヘ	14	ウンヘ	42	アンイ
15	アンヒ	43	ウンエ	15	イッケ	43	インヘ
16	ウッヘ	44	アッホ	16	アンケ	44	イッカ
17	イッコ	45	インオ	17	オン	45	インカ
18	イッキ	46	ウンホ	18	ウン	46	インケ
19	インイ	47	イッハ	19	イッホ	47	イッキ
20	ウッコ	48	アッカ	20	アンエ	48	アンヘ
21	アンイ	49	イン	21	イッヒ	49	イッハ
22	アンホ	50	ウンヘ	22	アン	50	アッカ
23	アン	51	アッコ	23	ウッケ	51	アンホ
24	エン	52	インケ	24	アッコ	52	アッホ
25	インヒ	53	アンア	25	インア	53	インエ
26	アンオ	54	インキ	26	アンヒ	54	ウンエ
27	ウン	55	アンハ	27	ウッヘ	55	アンカ
28	ウンオ			28	ウッコ		

B. Graphs

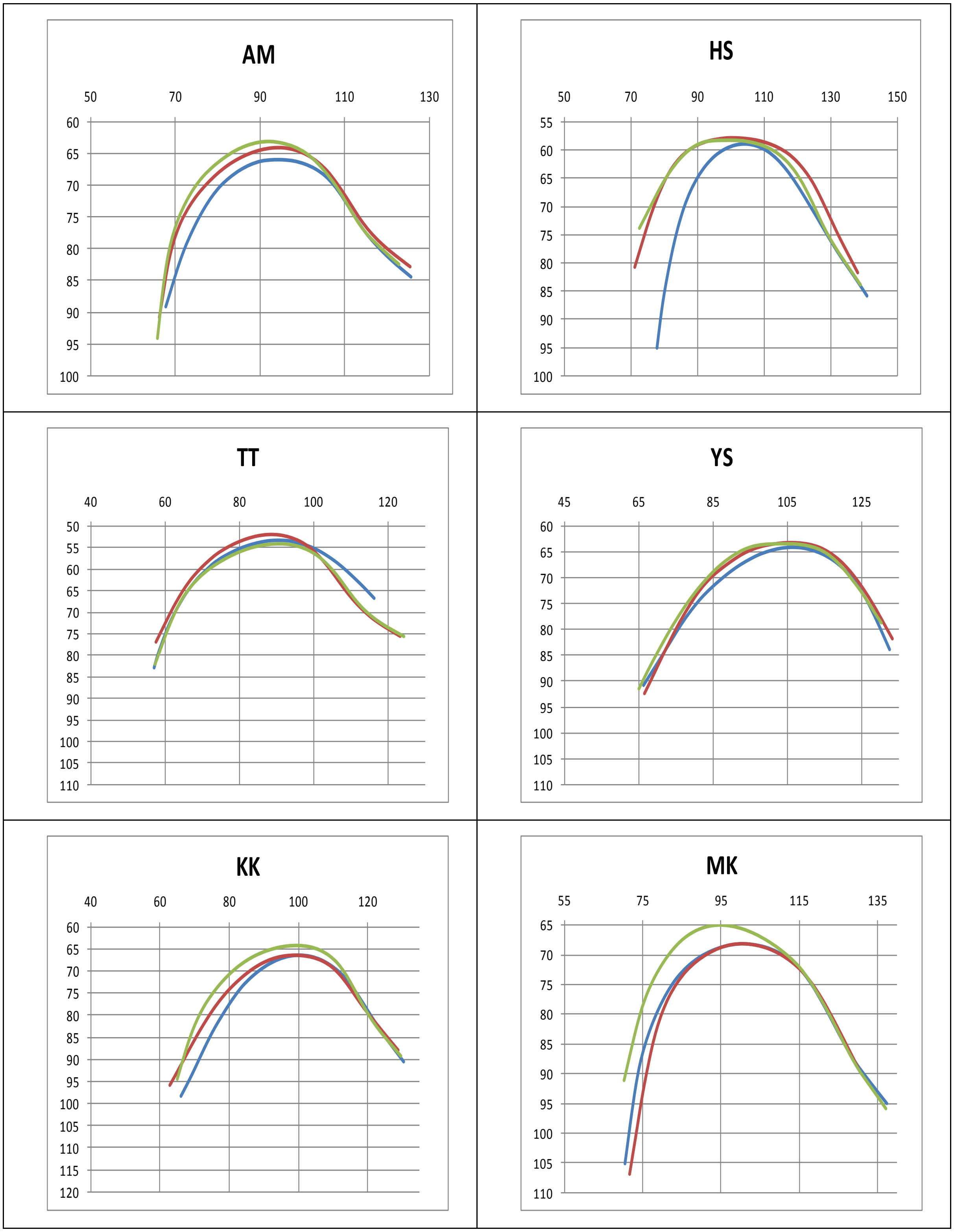

Figure B. 1. Average Tracings: *ihhi*, *iNi*, *ikki* (blue=h, red=N, green=k)

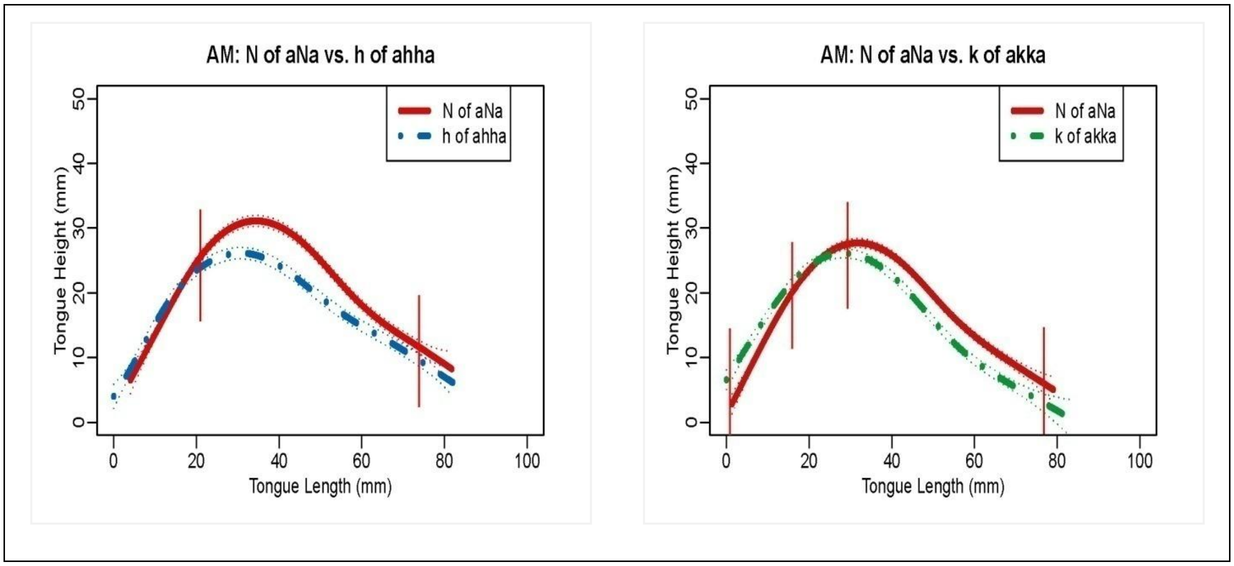

Figure B. 2. SS-ANOVA tongue-contour graphs: AM: (i) *aNa* vs. *ahha*, (ii) *aNa* vs. *akka*

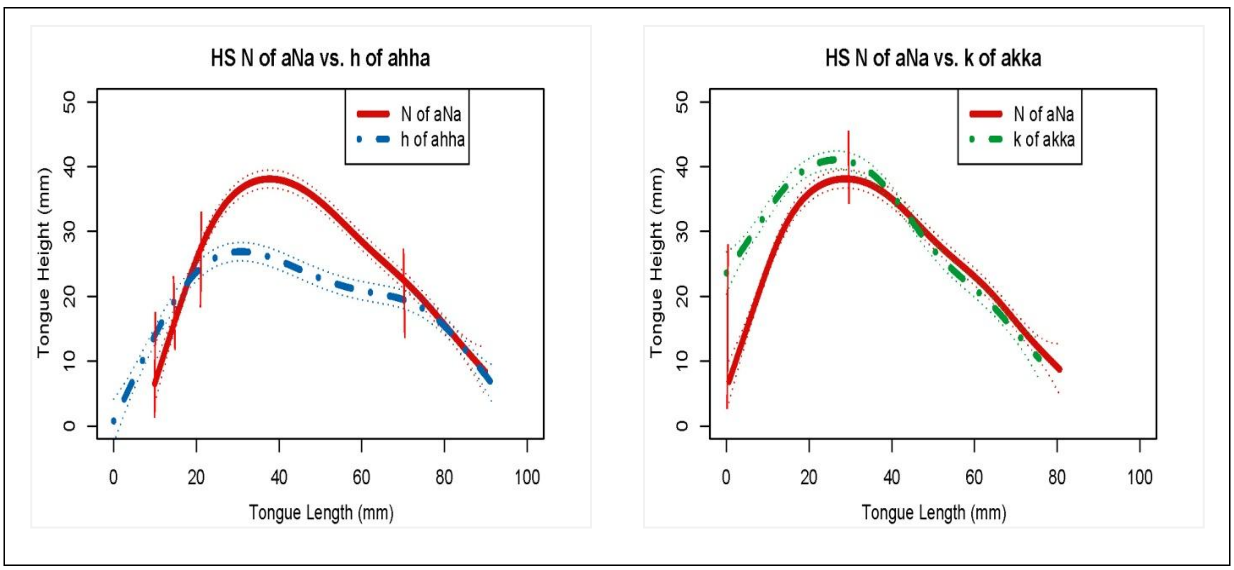

Figure B. 3. SS-ANOVA tongue-contour graphs: HS: (i) *aNa* vs. *ahha*, (ii) *aNa* vs. *akka*

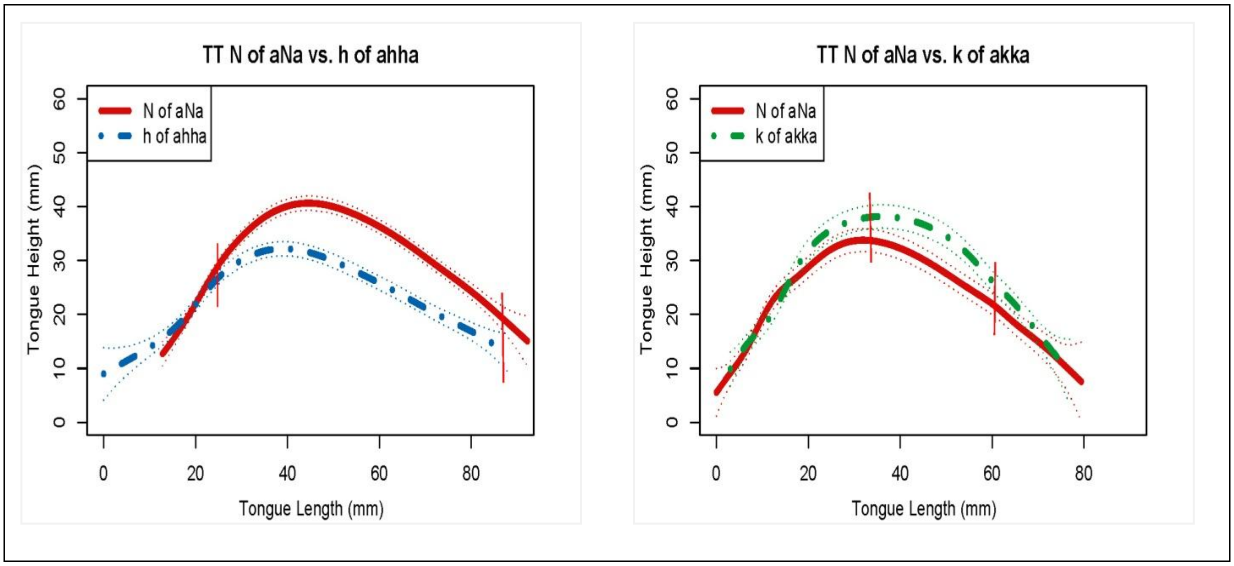

Figure B. 4. SS-ANOVA tongue-contour graphs: TT: (i) *a<u>N</u>a* vs. *a<u>hh</u>a*, (ii) *a<u>N</u>a* vs. *a<u>kk</u>a*

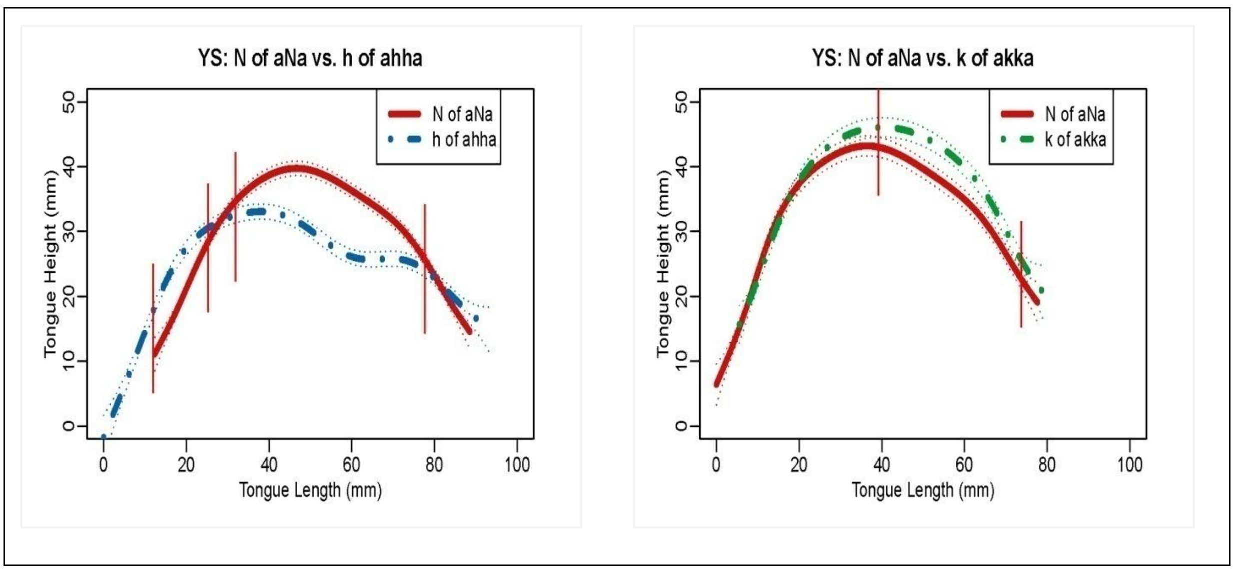

Figure B. 5. SS-ANOVA tongue-contour graphs: YS: (i) *a<u>N</u>a* vs. *a<u>hh</u>a*, (ii) *a<u>N</u>a* vs. *a<u>kk</u>a*

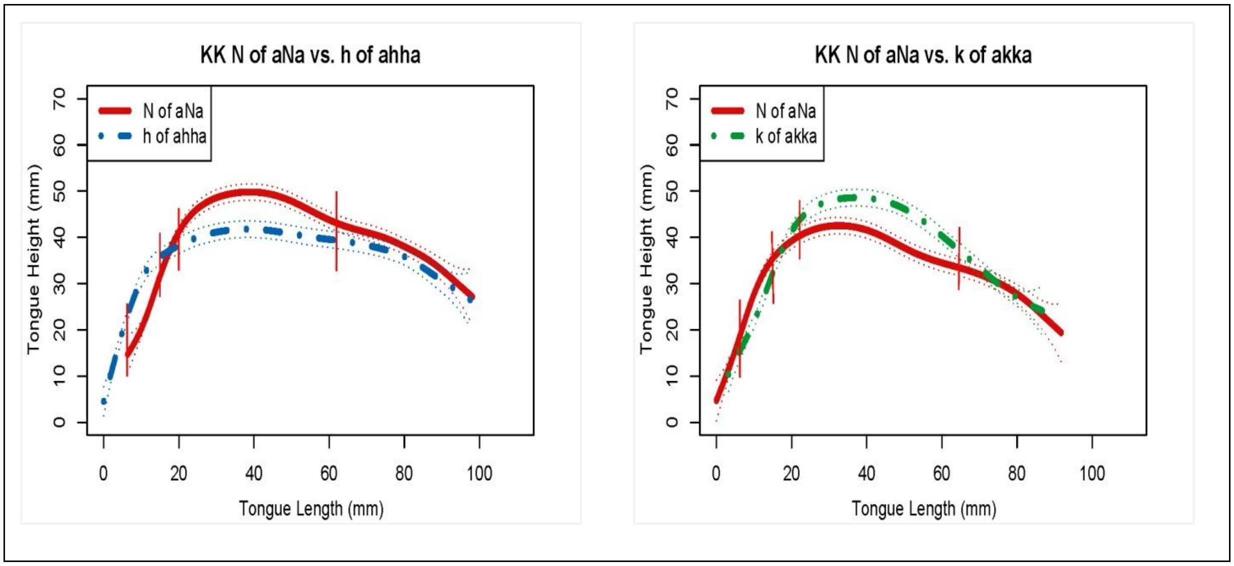

Figure B. 6. SS-ANOVA tongue-contour graphs: KK: (i) *aNa* vs. *ahha*, (ii) *aNa* vs. *akka*

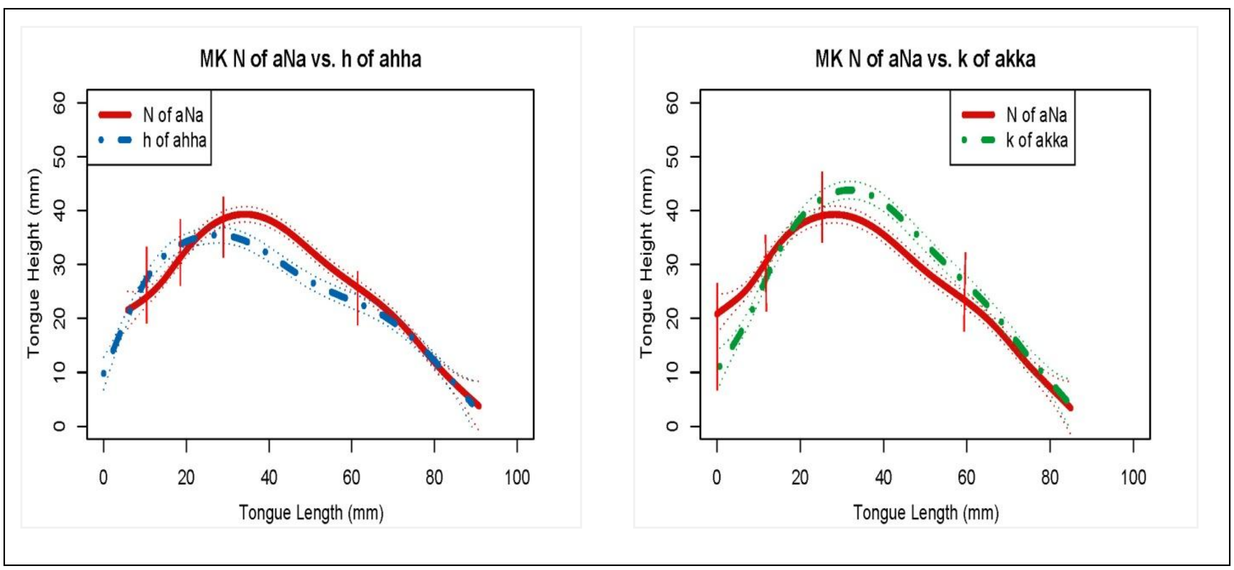

Figure B. 7. SS-ANOVA tongue-contour graphs: MK: (i) *aNa* vs. *ahha*, (ii) *aNa* vs. *akka* [74]

[74] Graphs show that N is significantly different from both /h/ and /k/ (>.05). In general, N shape looks similar to /k/ rather than /h/, except one speaker: KK's N is more similar to /h/.

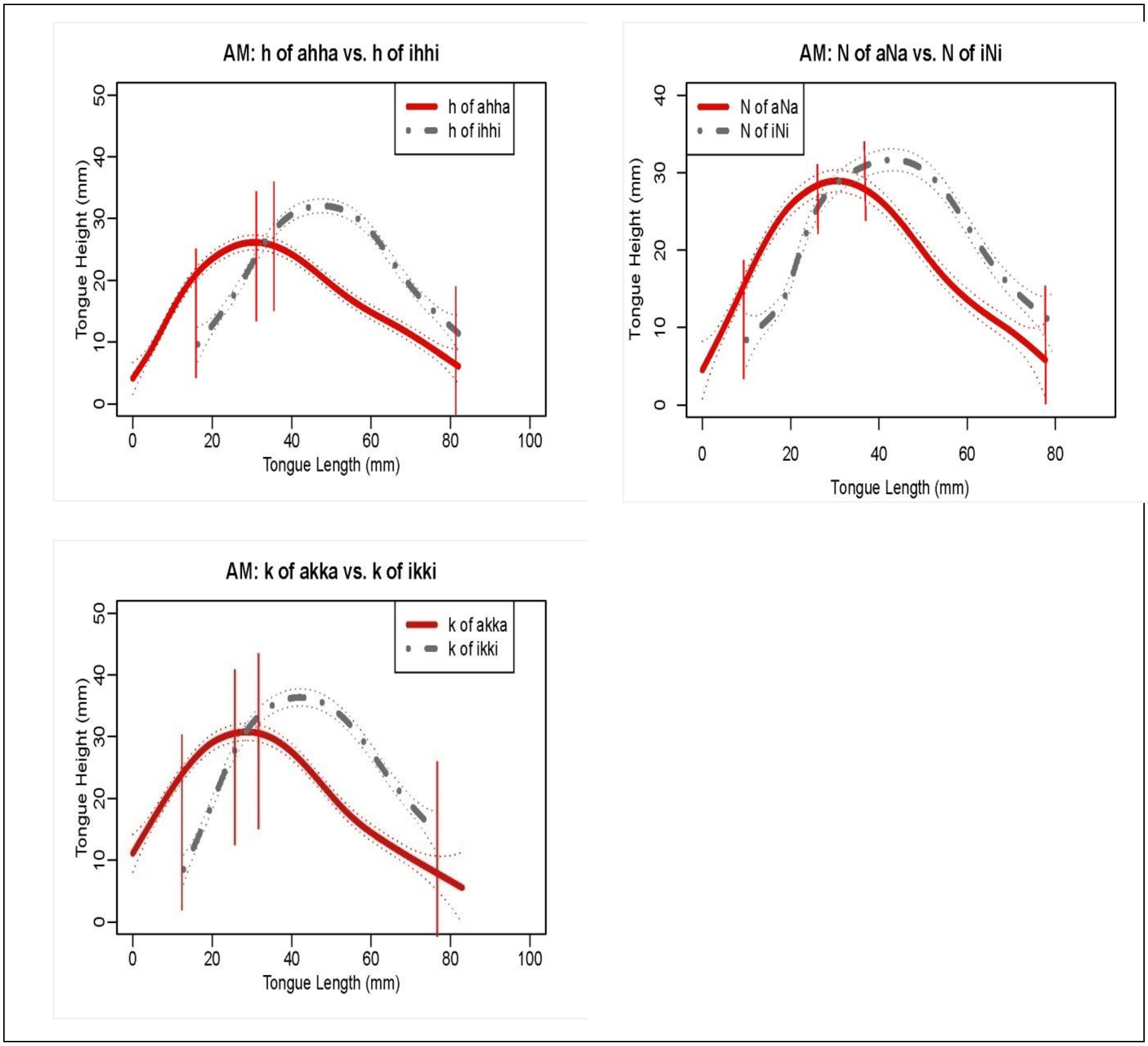

Figure B. 8. SS-ANOVA tongue-contour graphs: AM: (i) *a<u>h</u>ha* vs. *i<u>h</u>hi*, (ii) *a<u>N</u>a* vs. *i<u>N</u>i*, (iii) *a<u>k</u>ka* vs. *i<u>k</u>ki*

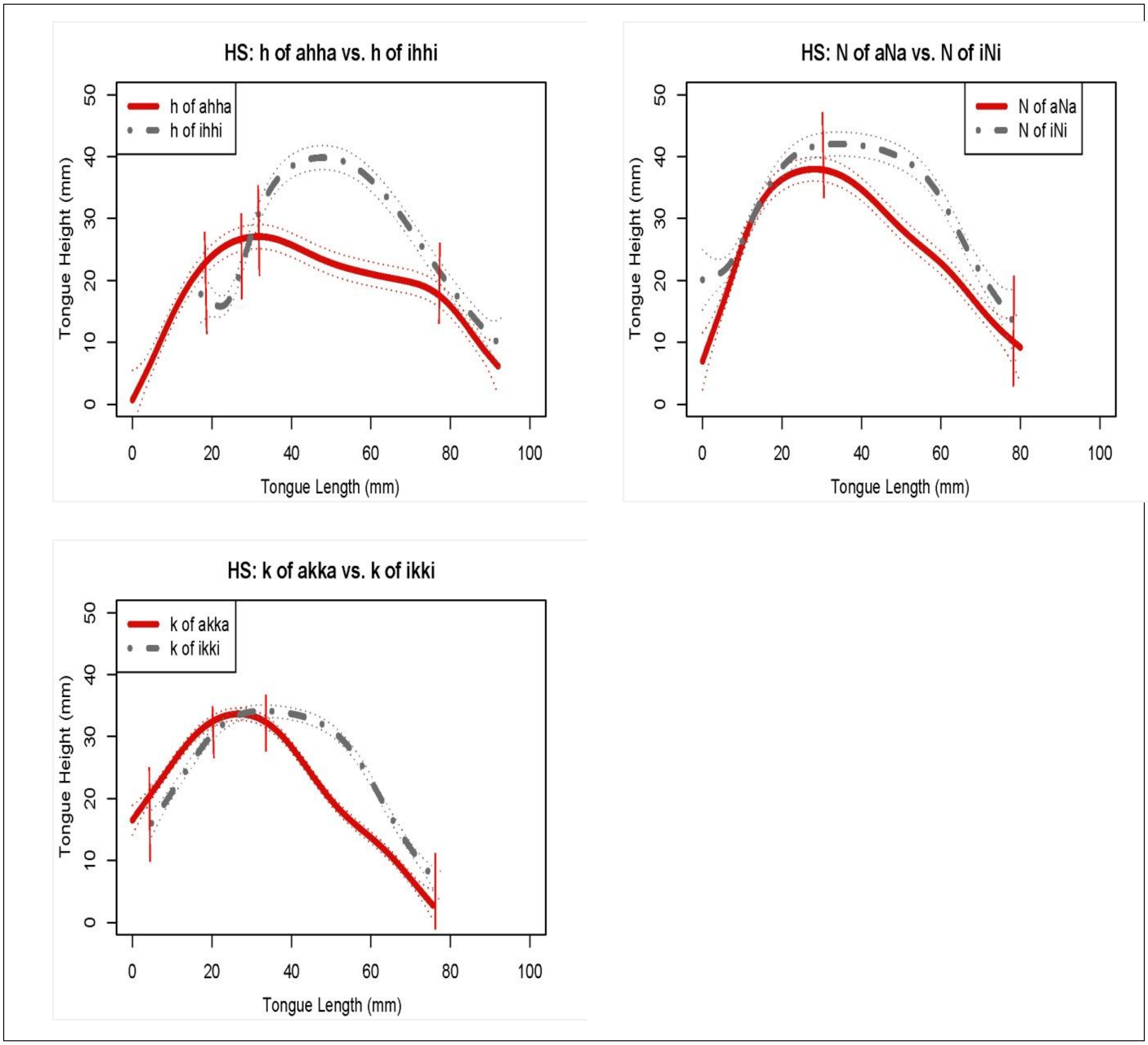

Figure B. 9. SS-ANOVA tongue-contour graphs: HS: (i) *ahha* vs. *ihhi*, (ii) *aNa* vs. *iNi*, (iii) *akka* vs. *ikki*

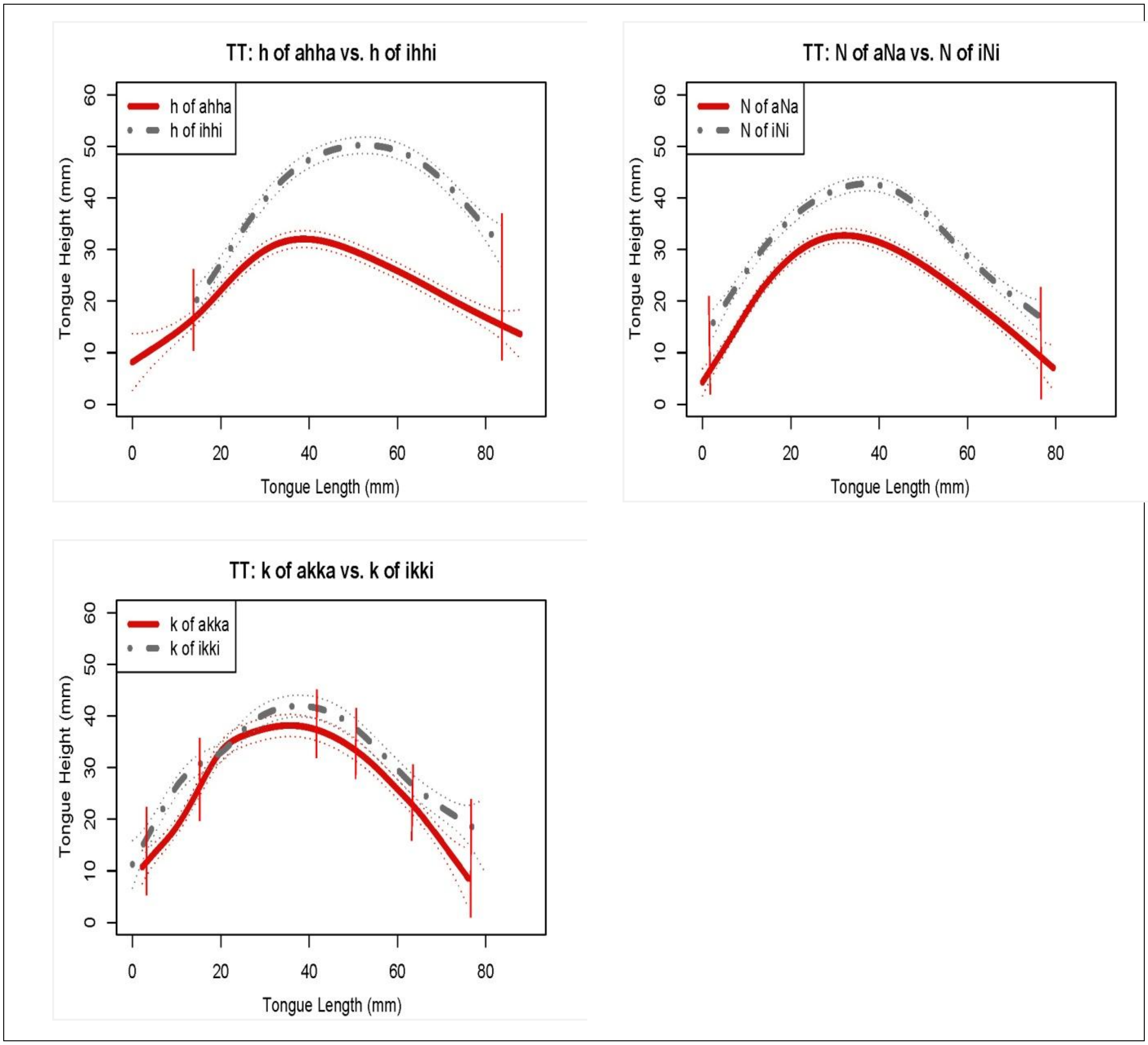

Figure B. 10. SS-ANOVA tongue-contour graphs: TT: (i) *a<u>hh</u>a* vs. *i<u>hh</u>i*, (ii) *a<u>N</u>a* vs. *i<u>N</u>i*, (iii) *a<u>kk</u>a* vs. *i<u>kk</u>i*

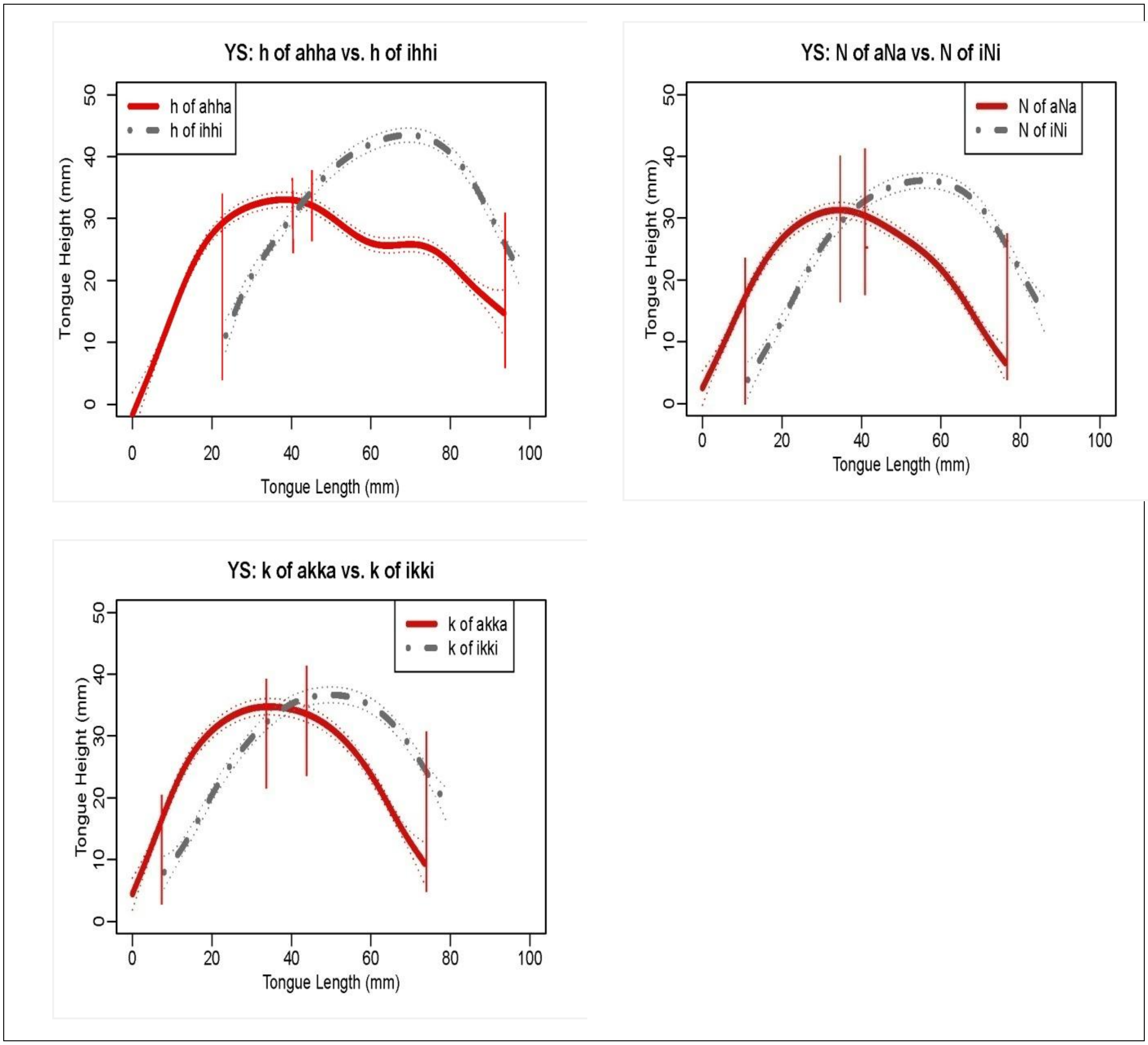

Figure B. 11. SS-ANOVA tongue-contour graphs: YS: (i) *ahha* vs. *ihhi*, (ii) *aNa* vs. *iNi*, (iii) *akka* vs. *ikki*

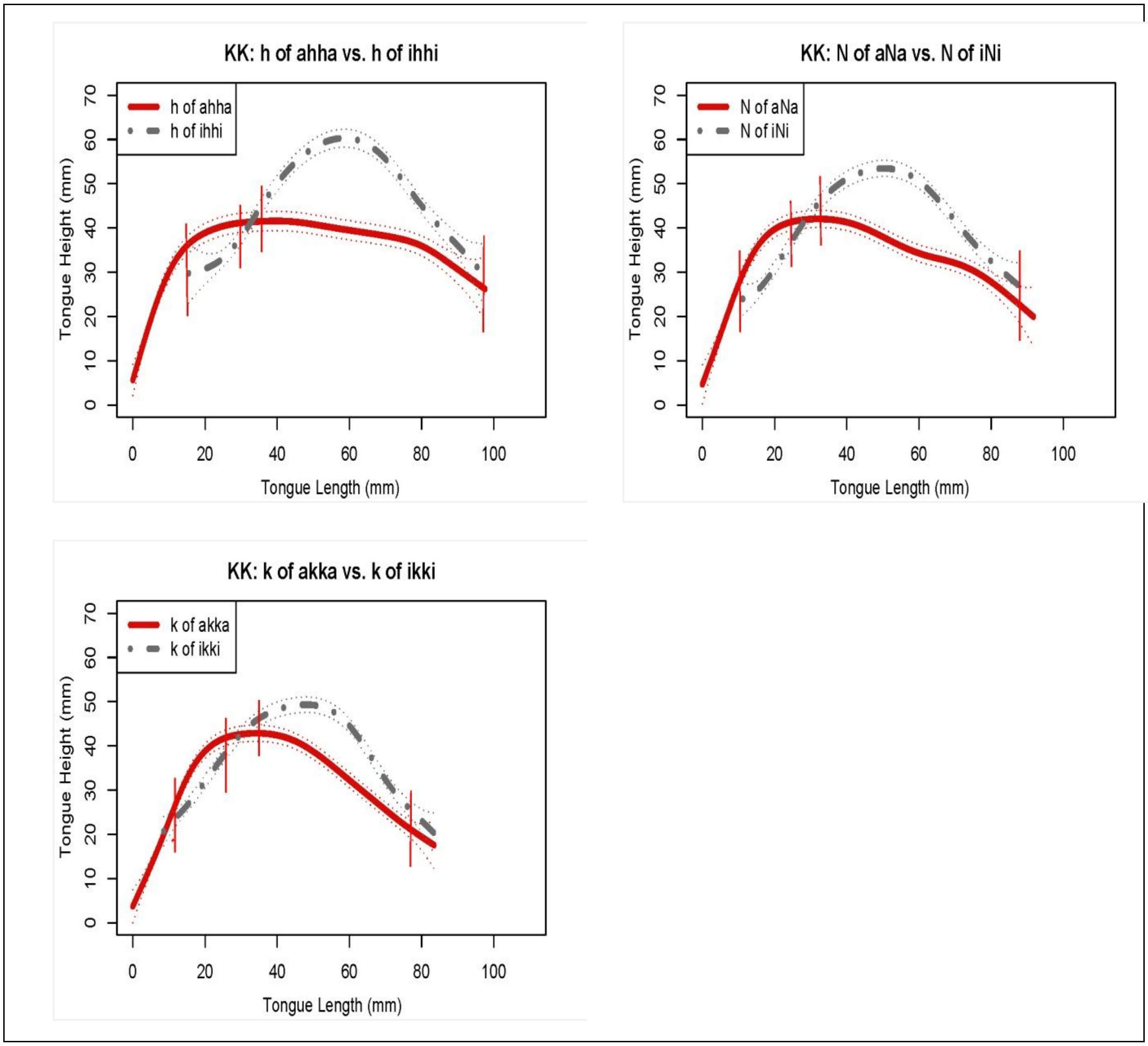

Figure B. 12. SS-ANOVA tongue-contour graphs: KK: (i) *a<u>h</u>ha* vs. *i<u>h</u>hi*, (ii) *a<u>N</u>a* vs. *i<u>N</u>i*, (iii) *a<u>k</u>ka* vs. *i<u>k</u>ki*

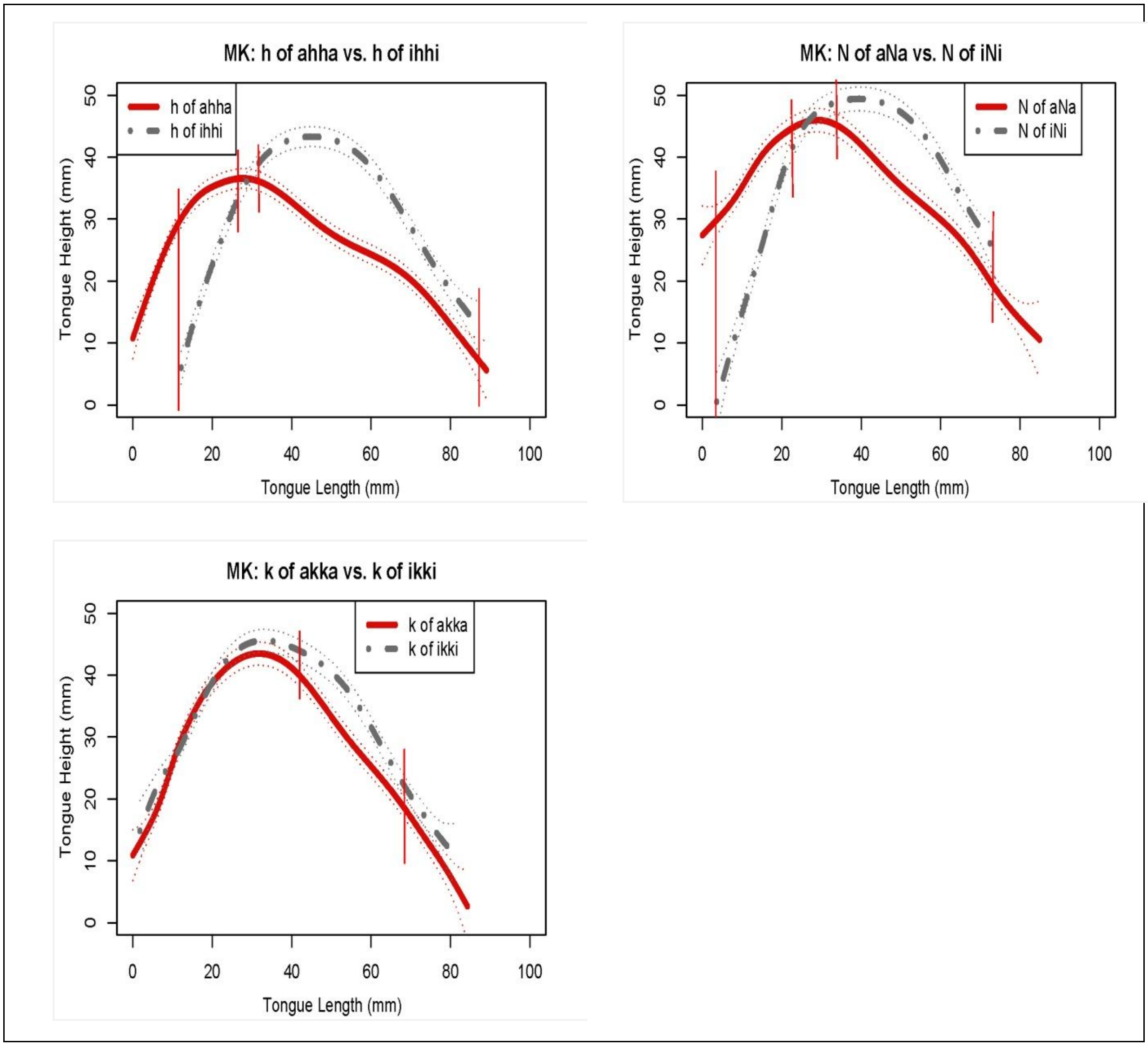

Figure B. 13. SS-ANOVA tongue-contour graphs: MK: (i) *a<u>hh</u>a* vs. *i<u>hh</u>i*, (ii) *a<u>N</u>a* vs. *i<u>N</u>i*, (iii) *a<u>kk</u>a* vs. *i<u>kk</u>i*

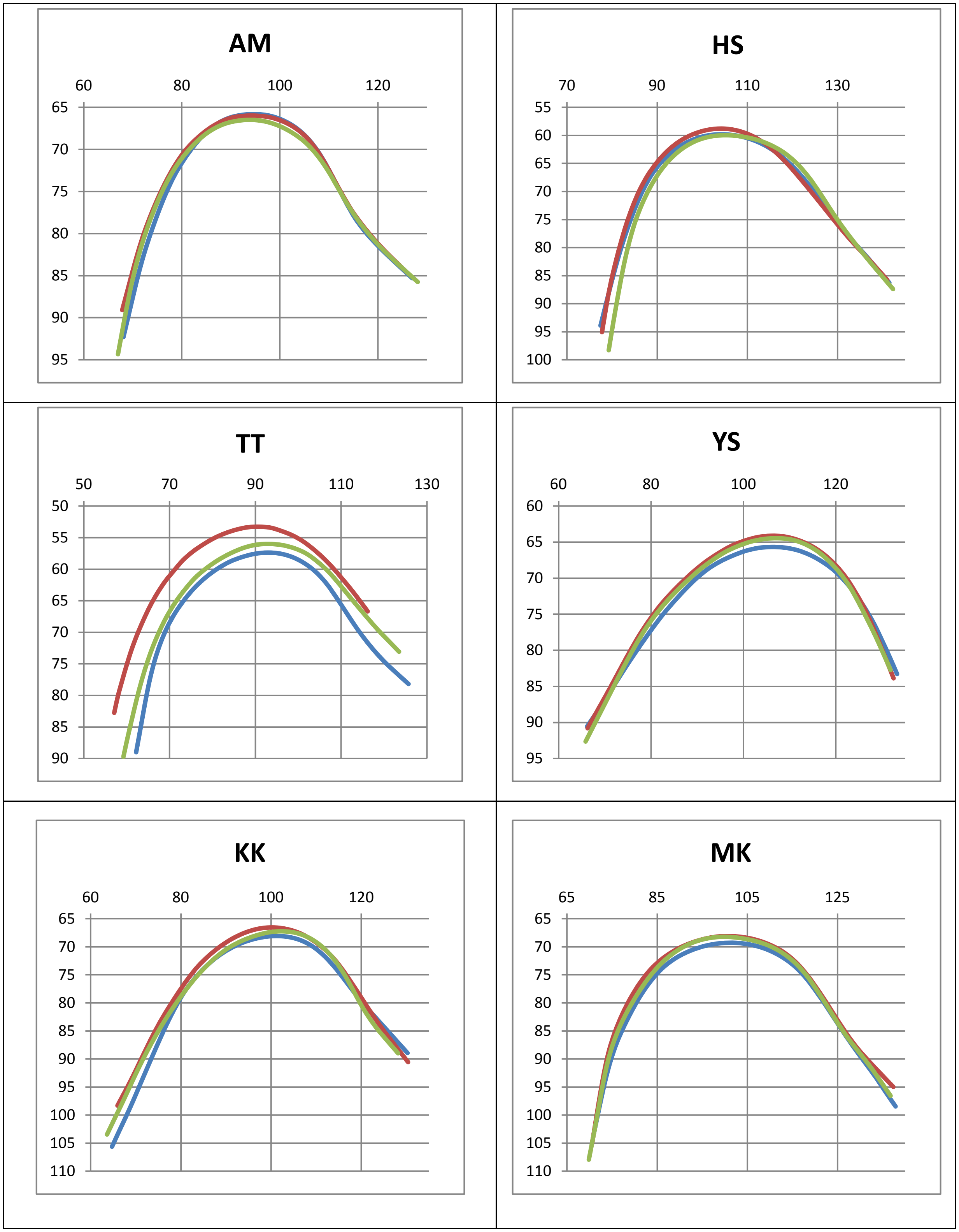

Figure B. 14. Average tracing /ihhi/ for all speakers

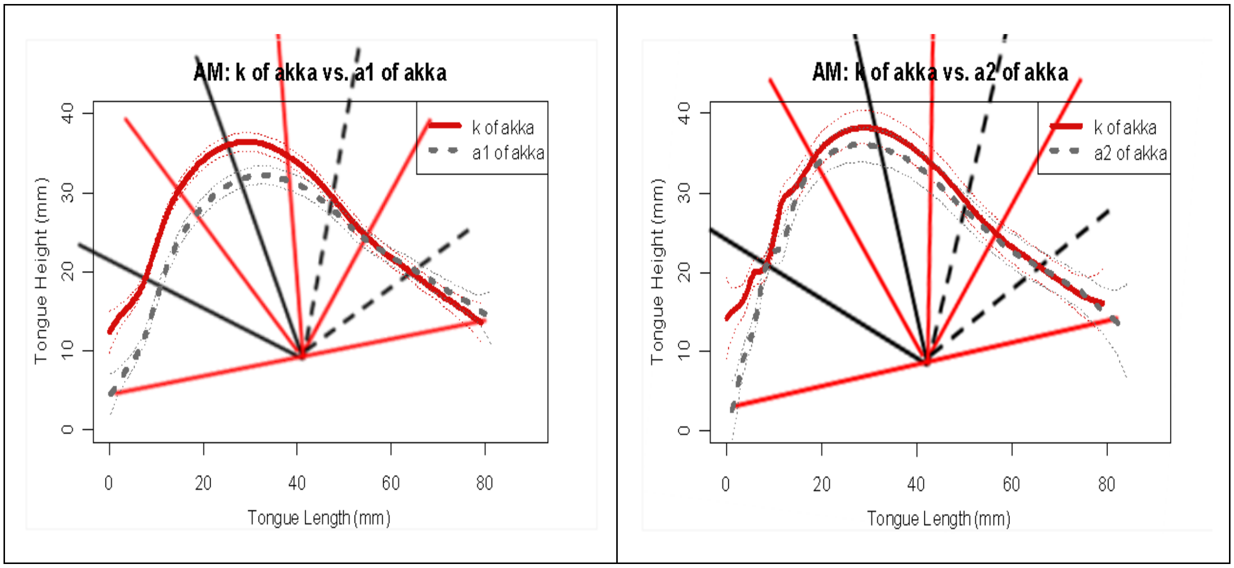

Figure B. 15. SS-ANOVA tongue-contour graphs: AM: (i) *akka* vs. *akka*, (ii) *akka* vs. *akka*

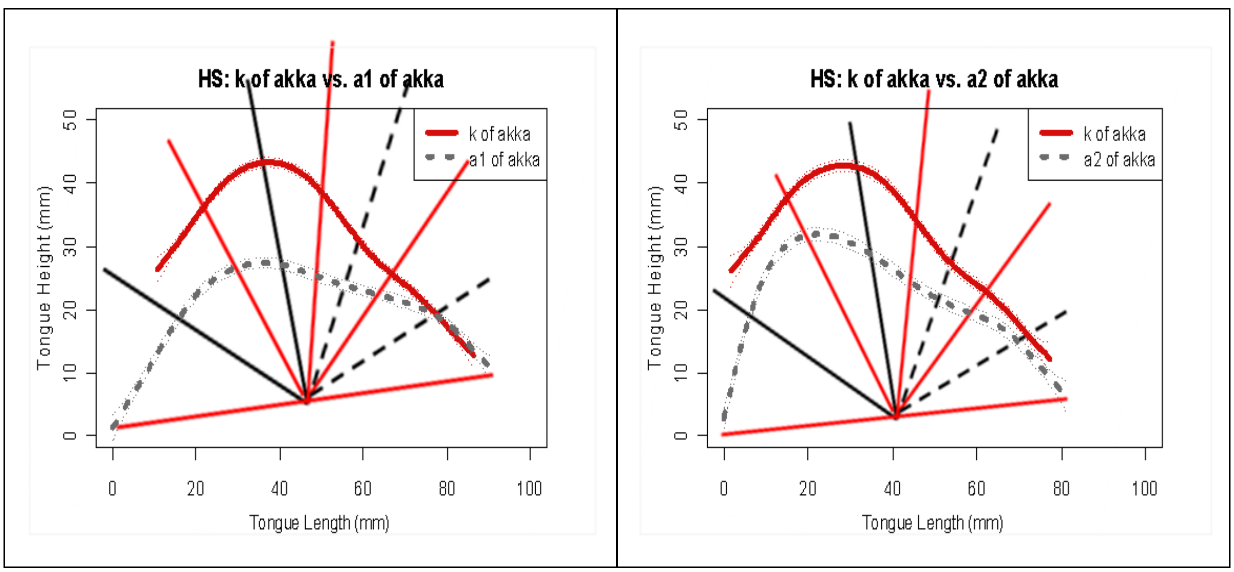

Figure B. 16. SS-ANOVA tongue-contour graphs: HS: (i) *akka* vs. *akka*, (ii) *akka* vs. *akka*

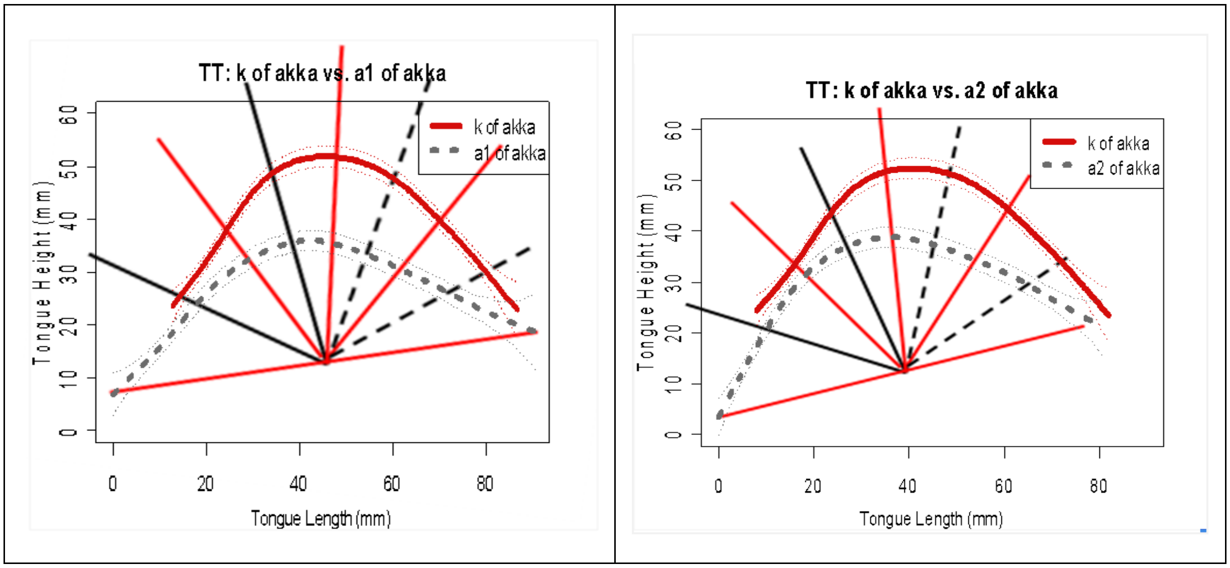

Figure B. 17. SS-ANOVA tongue-contour graphs: TT: (i) *akka* vs. *akka*, (ii) *akka* vs. *akka*

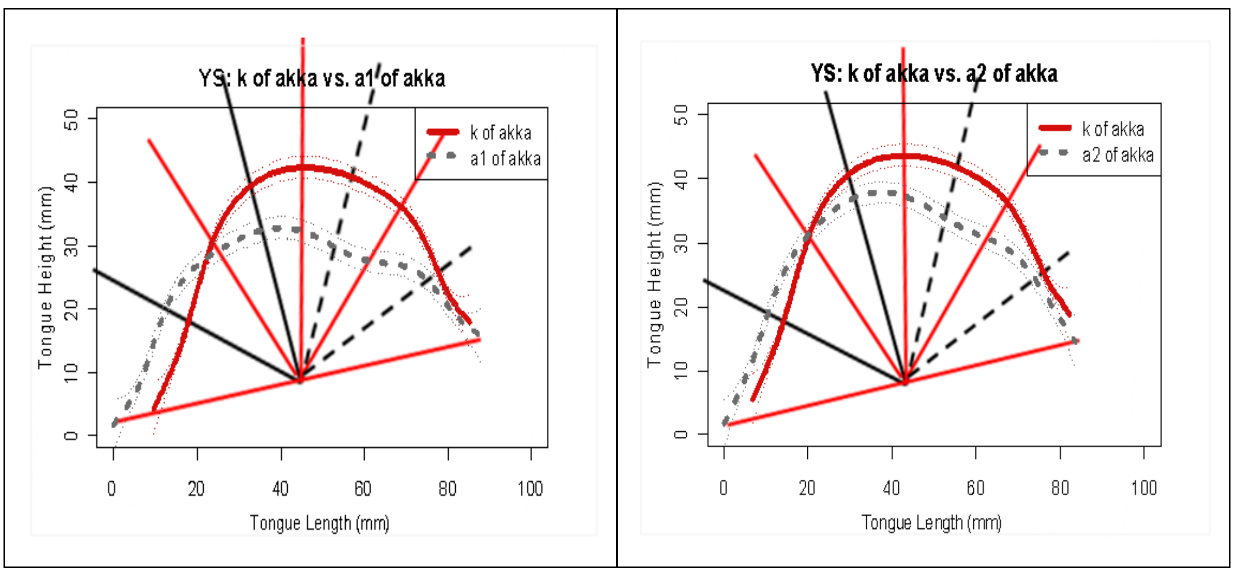

Figure B. 18. SS-ANOVA tongue-contour graphs: YS: (i) *akka* vs. *akka*, (ii) *akka* vs. *akka*

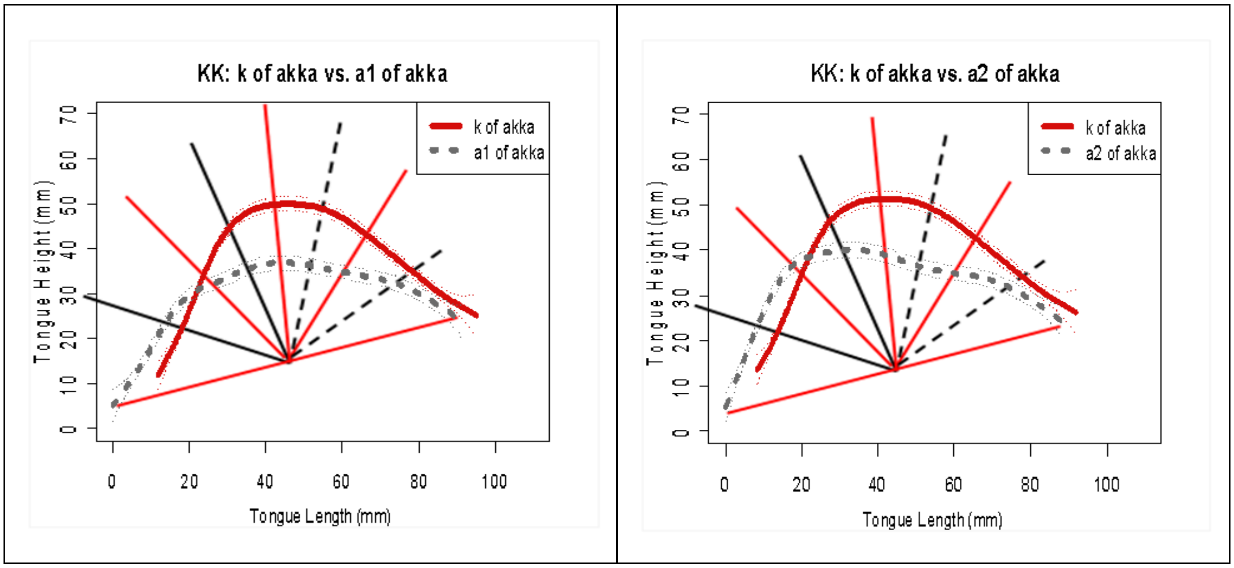

Figure B. 19. SS-ANOVA tongue-contour graphs: KK: (i) *akka* vs. *akka*, (ii) *akka* vs. *akka*

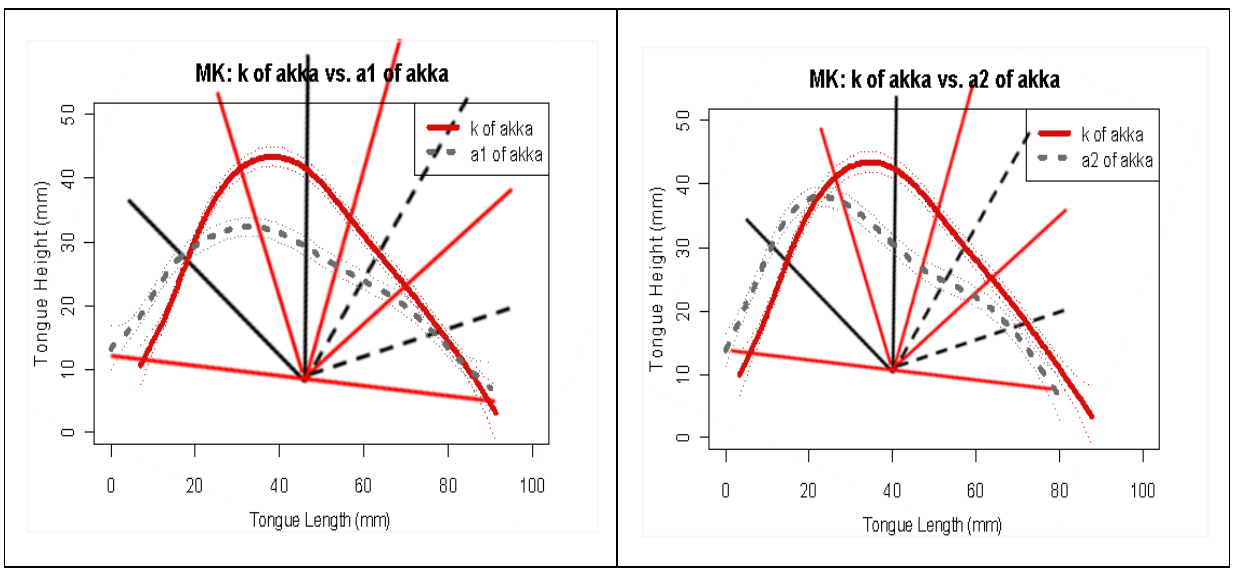

Figure B. 20. SS-ANOVA tongue-contour graphs: MK: (i) *akka* vs. *akka*, (ii) *akka* vs. *akka*