Agha Ali Raza, Mansoor Pervaiz, Waqas Iqbal

Existence of Velar Nasal Stops in Urdu

Abstract: *This paper aims to investigate the existence of the voiced velar nasal stop (“Ingma” / ŋ /) and unvoiced velar nasal stop (“Inkma” -analogous to Ingma- / ŋ̥ /) in Urdu Language, respectively. The presence of the velar nasal stops in Urdu Language is scrutinized on the basis of phonetic and phonological analysis.*

Keywords: *Urdu, Ingma, Inkma, nasal, velar, velopharyngeal port.*

1. INTRODUCTION

Speech comprises of phonemes and in languages certain phonemes are found to be in common occurrences and some are not. The phonemes of languages (that are used for computational simulation and recognition purposes) require that the phonemic inventory of a language is completely defined and standardized.

Urdu is rich language; yet, it has suffered greatly in this regard, as no extensive efforts to completely standardize its phonemic inventory are visible. As a consequence Urdu has lagged behind other languages as far as computational research is concerned.

In this paper the existence issues of the voiced velar nasal stop and unvoiced velar nasal stop are discussed. Though, the voiced velar nasal stop (“Ingma” /ŋ/) is present in many languages, but the unvoiced velar nasal stop (“Inkma”- analogous to Ingma / ŋ̥ /) has not yet been defined as a sound in any language [5].

This paper is written with an endeavor to examine the existence of Ingma by slightly altered reasons from [3] and [4] because of certain glitches found in the reasoning of the stated papers and also to investigate the presence of Inkma in Urdu on phonological and phonetic grounds. Hopefully, this will be a small contribution in the definition of the phonemes of Urdu language for progress in the development of Urdu computation.

2. LITERATURE REVIEW

This section presents a brief review of the literature available about the characteristics of Ingma in general and its phonemic existence in Urdu Language.

Mostly, all speech sounds are uttered as a result of the outward rush of air from the lungs (acting as the pumping source), which, while its passage through the glottal folds causes their rapid vibrations (Bernoulli’s effect), as stated by [2]. The sound waves hence generated are then modified by their propagation through anyone, or both of the outward opening namely, the vocal and the nasal tracts, resulting in the formation of respective sounds. The former ones being further modified by exploiting the articulatory capabilities of the tongue, teeth and lips in such a way that airflow through the oral cavity is radically constricted or even temporarily blocked as in [2].

The nasal sounds are characterized by the complete occlusion of the vocal tract at any of its intermediate places, hence modifying the length of the thus formed auxiliary vocal tube. The velopharyngeal port is opened to allow the egress of the resulting sound waves, which due to extensive resonance and interference in, primarily, the nasal cavity, and secondarily, the auxiliary vocal tube, are sufficiently lower in frequency. The sound hence resulting is called the nasal murmur, which is the characteristic indication of a nasal stop as in [1].

“The release of a nasal consonant is not accompanied by a burst because, due to the open state of the velar port, there has been no build-up of air pressure in the oral-pharyngeal cavity during the oral occlusion.” [1].

“There are two main differences distinguishing nasals and voiced stops that stem from the articulatory conditions during the oral occlusion: (1) The absence of presence of a release burst, and (2) the intensity of a murmur.” [1]

The velopharyngeal port opens well before the oral occlusion for the preparation of the velar consonant and remains open after it as in [1]. “The lead and lag of velar opening and closing, preceding and following the oral tract occlusion are typically about hundred milliseconds. This causes nasalization of portions of vowels for about 100 ms preceding and following the oral occlusions of nasal consonants.” [1]

Thus classifying a nasal stop. A nasal stop in which the oral tract is occluded at the place of velum is called a velar nasal stop. Depending on whether the vocal folds are sufficiently vibrating or not we can further classify the voiceless and voiced velar nasal stops as in [1].

As stated previously that some sounds do not occur in all languages but [3] and [4] affirm that the voiced velar nasal stop is present in Urdu language.

Reference [3] proves the existence of /ŋ / in Urdu by first explaining the behavior of the voiced alveolar nasal stop /n/ when it precedes a consonant. It is further stated that /n/ is always uttered at the place of the following consonant. Moreover, this argument is extended to the behavior of /n/ when it precedes the voiced velar stop /g/ where it is converted into the voiced velar nasal consonant (/ŋ /). Secondly, the existence of /ŋ / as an independent sound in Urdu is supported by the deletion of /g/ in the above mentioned process proved by the absence of the burst of /g/ in the spectrograms. This argument is further reinforced phonologically.

Reference [4] again proves the existence of /ŋ / in Urdu Language on the basis of the analysis of the nasal

band of /n/ which propagates up-to and ahead of /g/ which is considered a sufficient proof for the idea that the velopharyngeal port is open up till the utterance of /g/ and after it. On the same grounds [4] disproves the existence of /ŋ$_o$/ in which the nasal band finishes significantly before the burst of /k/. So the velopharyngeal port is closed before the utterance of the /k/. Furthermore, the paper also proves the existence of the aspirated voiced velar nasal stop (/ŋ^h /) when /n/ precedes the aspirated version of /g/ that is /g^h/. Moreover, to support these arguments the technique of minimal pairs is used to phonologically prove the existence of the aspirated and unaspirated /ŋ/.

3. PROBLEM STATEMENT

This paper attends to the issue of existence of velar nasal stops in Urdu Language on basis of phonetic and phonological analysis of speech recordings of Urdu speakers in Lahore (Pakistan).

4. METHODOLOGY

4.1 Selection of Words

We selected the words on the criterion that not only the voiced and unvoiced velar nasal (Ingma and Inkma) should be analyzed but the component sounds contributing to the formation of Ingma and Inkma should also be observed. Hence we included the pure versions of /g/, /k/ and /n/ in the word spectrum as well (see appendix A). In addition, to avoid any anomalies introduced by the occurrence of the consonants under observation at the word boundaries, we also tested the inter-vocalic versions of all these words as well, by introducing vowel /a/ at their ends, remaining well within the grammatical rules of Urdu.

4.2 Selection of Speakers

For phonetic analysis the selected words were recorded as spoken by six different speakers. The speakers that were selected were native speakers of Urdu (Lahori accent), three males and three females, and were unaware of the goal of the recordings. It was kept in consideration that no speaker had a nasal voice.

4.3 Recordings

The recording was carried out in a noise and echo free environment. Each speaker was made to speak the selection of the words in a carrier phrase. To ensure natural delivery of word the sentences were randomized and for unbiased and better results the words were not recited in front of the speakers. Also, the recordings were taken in five repetitions to avoid inconsistencies and discrepancies.

4.4 Recording Equipment

The equipment consisted of a high fidelity 600 ohms moving coil microphone, a Teac integrated stereo amplifier (power output 195 Watts per channel) and two high quality speakers with 8 ohms impedance. The recordings were digitalized at a sampling rate of 32000 samples per second.

4.5 Acoustic Analysis

The acoustic analysis of the speech was carried out using Praat 4.1.10 freely available at www.praat.org. For the acoustic analysis of the data, spectrograms were read to study bursts, closure durations, nasalization and its duration, voicing of alveolar nasal /n/ preceding velar stops /g/, /k/, voicing patterns of /g/ and /k/ in Ingma and Inkma respectively. The values of formants and bandwidths were evaluated from the spectrogram.

4.6 Phonological Analysis

The results of the acoustic analysis of the data were used to identify the phonological rules for ingma and Inkma. The assimilation of place, nasality, aspiration and voicing was studied to generate the phonological rules.

5. RESULTS

The results stated below are averages taken over the entire sample of data recorded from the speakers.

5.1 Closure Length

For closure length we have actually taken the part of the closure in which there is no nasal band (which is only in case of Ingma and Inkma).

5.1.1 Closure Length in /k/

In case of unvoiced non-nasal velar stop /k/, occurring independently (not intervocalic), the closure period was around 70 milliseconds. Whereas, while /k/ occurring intervocalically the closure period was approximately 90 milliseconds.

5.1.2 Closure Length in /g/

In case of voiced non-nasal velar stop /g/, occurring independently (not intervocalic), the closure period was around 40 milliseconds. Whereas, while /g/ occurring intervocalically the closure period was approximately 50 milliseconds.

5.1.3 Closure Length in /ŋ /

In case of voiced nasal velar stop /ŋ/, occurring at word end, there was a slight observable closure (about 3 to 5 ms) in most cases, as it was nearly filled with the nasal bands. It was observed from the absence of nasal bands and presence of voicing of /g/ in the closure. Similarly there was slightly visible closure in /ŋ / occurring intervocalically which was around 8 milliseconds.

5.1.4 Closure Length in /ŋ$_o$/

In case of voiceless nasal velar stop /ŋ$_o$/, occurring at word end, the closure period was around 35 milliseconds. Whereas, in intervocalic /ŋ$_o$/ the closure period was around 50 milliseconds.

From the above results it is observed that the closure period of /g/ is almost half of the closure period of /k/ in intervocalic and word end case. The visible closure period in /ŋ/ is approximately 3 to 8 milliseconds and the closure period in /ŋ$_o$/, other than the one filled with the nasal band, was half of that of /k/.

Table 1

Speakers		#1	#2	#3	#4	#5	#5	Std Dev	Average
Closure of /g/	*Word Final*	0.04	0.047	0.05	0.05	0.03	0.04	0.007757	0.04283
	Intervocalic	0.04	0.06	0.05	0.05	0.04	0.06	0.008944	0.05
Closure of /k/	*Word Final*	0.06	0.08	0.07	0.09	0.06	0.05	0.01472	0.06833
	Intervocalic	0.08	0.11	0.08	0.1	0.09	0.07	0.01472	0.08833
Nasalization of /n/	*Word Final*	0.07	0.079	0.1	0.08	0.07	0.09	0.011726	0.0815
	Intervocalic	0.1	0.07	0.08	0.1	0.05	0.08	0.018974	0.08
Empty Closure of /g/ in Ingma	*Word Final*	0	0.01	0	0.01	0	0	0.005164	0.00333
	Intervocalic	0	0.03	0.01	0	0	0.01	0.01169	0.00833
Nasal band in Ingma	*Word Final*	0.07	0.07	0.08	0.09	0.08	0.07	0.008165	0.07666
	Intervocalic	0.08	0.06	0.07	0.08	0.08	0.07	0.008165	0.07333
Empty Closure of /k/ in Inkma	*Word Final*	0.05	0.03	0.04	0.039	0.03	0.03	0.008093	0.0365
	Intervocalic	0.04	0.1	0.04	0.04	0.04	0.04	0.024495	0.05
Nasal band in Inkma	*Word Final*	0.06	0.07	0.06	0.092	0.055	0.06	0.013571	0.06616
	Intervocalic	0.08	0.04	0.07	0.09	0.08	0.06	0.017889	0.07

5.2 Nasal Band Length

The nasal band in /k/ and /g/ was naturally not visible but in case of /n/, appearing both at word final and intervocalically, the length of the nasal band was around 80 milliseconds.

In case of /ŋ/ the length of the nasal band was around 75 milliseconds in both cases, and in case of /ŋ$_o$/ the length of the nasal band was around 70 milliseconds.

So in both /ŋ/ and /ŋ$_o$/ as well as the alveolar nasal stop /n/ the length of the nasal bands remains almost constant.

5.3 Effects of Nasalization

In /ŋ/ the voicing of /g/ is clearly present in the closure period and in /ŋ$_o$/ the unvoiced behavior of /k/ is retained. Therefore, the /n/ preceding the velar consonant is although uttered at the velar place as in [3] yet it does not prevent the phonation (voicing behavior) of the respective consonants.

It was observed that in both /ŋ/ and /ŋ$_o$/ the preceding vowels is always nasalized. But, the following vowel is never nasalized.

5.4 Burst of Velar Stops

It was observed that the burst of /g/ is always present in the spectrogram of /ŋ/ also it does not always merge with the nasal bands. Similarly, in case of /ŋ$_o$/ the burst of /k/ is always present in its spectrogram but it does not merge with the nasal bands at all. It is also notable that in all the spectrograms it is evident that the velar stops are always released.

6. DISCUSSION

6.1 Phonetic Inference

6.1.1 Burst of /g/ in /ŋ / and /ŋ$_o$/

All the recordings definitely confirmed that the burst of /g/ is never absent from the spectrogram of the proposed Ingma and therefore /g/ is never deleted from ingma contrary to the statement by [4] which was that the burst of /g/ was not present in /ŋ /. We also investigated the cause of this incoherent assertion and came up with the following deduction:

The duration of closure of /g/ is much smaller than that of /k/. In both /ŋ/ and /ŋ$_o$/ the period of the nasal bands remains constant as a result sometimes it appears to span the whole length of closure in /g/ contrary to its behavior in case of /k/ where it definitely stops shorter. But in all cases:

- In the spectrogram of /ŋ/ both /n/ and /g/ coexist
- In the spectrogram of /(o/ both /n/ and /k/ coexist

But it is very important to note that these /n/ patterns correspond to the “noon ghunna” rather than the pure “noon” (/n/), where, orthographically “noon ghunna” in Urdu is the /n/ in which the previous vowel is nasalized as in [3].

The above mentioned behavior and the definite presence of the burst of /g/ in /(/ comprehensively proves that the velopharyngeal port is closed well before /g/, as a result the release in the air pressure in the velopharyngeal regions, which was build up after the closure of the velopharyngeal port and before the release of oral occlusion, produces the burst of /g/ which is clearly visible in figure 1. So this may be depicted as a proof of the proposition that ingma does not exist, at least, in that part of the spectrogram where it was generally suspected to be found

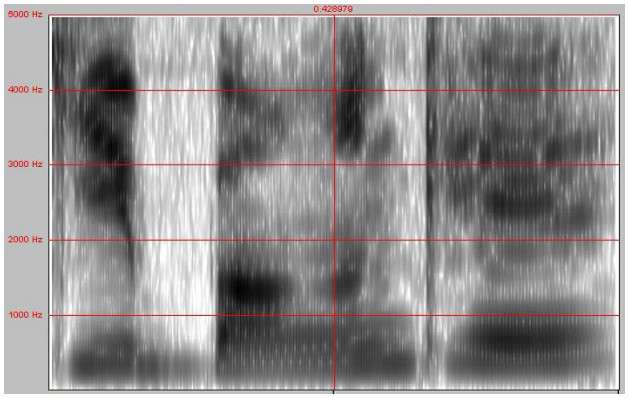

FIGURE 1: Spectrogram of "yeh rang hai"

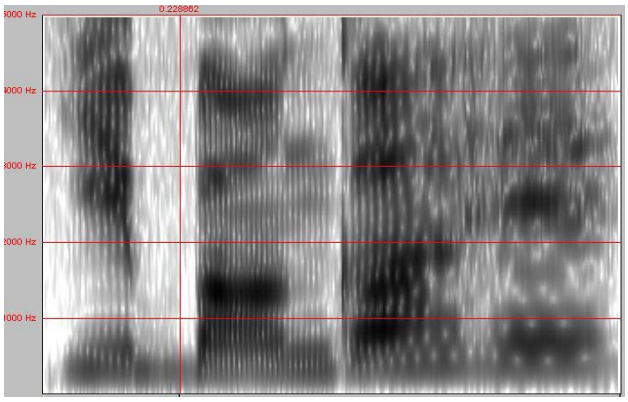

FIGURE 2: Spectrogram of "yeh ranga hai"

i.e. in the region after the vowel preceding /n/ up till and including /g/.

6.1.2 Voiceless and Voiced /k/ and /g/ in /ŋ/ and /ŋ$_o$/

/n/ preceding any consonant does not prevent its phonation nor distorts it (as /n/ is voiced and any amalgam containing it should have its effect upon it). But, in the supposed /ŋ/ the /g/ is there as the voiced velar consonant and in the proposed /(o/ the /k/ is there as the unvoiced velar consonant. Hence it is notable that both /g/ and /k/ along with their phonation are always present in the supposed /ŋ/ and /ŋ$_o$/, which is contrary to the definitions of /ŋ/ and /ŋ$_o$/ as independent voiced velar nasal stops in which the /g/ and /k/ should be part of the respective sound rather existing as independent velar stops (along with their phonations and bursts). This again proves that if ingma exists at all in these spectrograms it ends well before the start of /k/ and/or /g/.

6.1.3 Fading of Nasal Bands

A careful scrutiny of the spectrograms of supposed /ŋ/ and /ŋ$_o$/ reveals that, often the nasal band in /ŋ/ reach up to the place where /g/ is uttered. If at this time the reader of the spectrogram some how ignores the significance of the burst of /g/ he can be seriously mislead to the erroneous conclusion that /n/ and /g/ are amalgamating together to produce a new sound. However, this behavior can be easily explained by the analysis of the data presented in table 1.

Upon observing the trend of nasal bands when they occur in the alveolar nasal /n/ and in the proposed ingma and Inkma, they are found to retain an almost constant duration of around 70 milliseconds in all these cases.

The closure duration of /g/ was observed to be around 40 milliseconds, where as that of /k/ somewhere in the proximity of 75 milliseconds.

Here if it is assumed that total length of closure of /k/ in /ŋ$_o$/ is the same as that of pure /k/ then by observing table 1 we find that nearly 35 to 45 milliseconds of the closure are always devoid of nasal bands. This implies that the nasal bands fill up about 35 ms of the total 75 ms burst of /k/. If this supposition is extended to /ŋ / then the closure of /g/ should be filled for the first 35 ms and the last 3 to 8 ms should be empty. Rows seven and eight of the table 1 confirm these suppositions.

Therefore, it can be concluded that the nasal bands, and hence nasalization, definitely finishes before the utterance of the velar consonant /g/. The gradual fading and ending of nasal bands corresponds with the closure of the velopharyngeal port, which in-turn is the indication of the end of /n/. As all this happens before /g/, it means the velopharyngeal port closes before the removal of oral occlusion. This behavior clearly shows that /g/ and /k/ are always occurring as independent phonemes in the recorded spectrograms rather than being a composite sound of /ŋ / or /ŋ$_o$/. /ŋ / or /ŋ$_o$/; If they exist in these spectrograms, must be ending before the utterance of these consonants.

6.1.4 Nasalization of the following vowel

According to [1], a very important property of all nasal consonants, occurring intervocalically is that, the last 100 ms of the previous vowel and the first 100 ms of the following vowel are nasalized. When tested, it was found that, in case of both /ŋ / and /ŋ$_o$/ the vowel preceding the supposed /ŋ / and /ŋ$_o$/ is always nasalized proving that the start is nasal but the vowel following the consonants is always non-nasal showing that the consonant prior to the vowel is non-nasal meaning it is neither /ŋ / and /ŋ$_o$/ nor it is /n/.

This non-nasal character of the following vowel betrays the fact that the nasalization ended some where before the previous consonant (in this case velar consonant) as was stated in 6.1.3. So it can be safely stated that the last consonant is not a part of /ŋ / or /ŋ$_o$/ or any other nasal consonant.

6.1.5 The Nasal Region

Until now our studies are following the same line as was done by our predecessors as far as the suspected region of the existence of /ŋ / or /ŋ$_o$/ is concerned. However, results prove that there is no existence of ingma spanning this region as a whole. But, if we just concentrate on the region just behind the bursts of /k/ and /g/ we observe the following details:

- There is no burst in this region.
- There are continuous nasal bands, which fits into the definition of the "Nasal Murmur". [1]
- Previous vowel is nasalized.
- Whole of the region has definite voicing.
- The region around 5000 Hz is definitely lighter corresponding to a zero (area formed as a result of destructive interference (anti resonance)), which is a property of /ŋ /. [1]
- The murmur spectrum is stronger in low frequency regions, which is a property of /ŋ /. [1]

All these arguments support the proposition that the part of the spectrogram that exists before the burst of /g/ and the burst of /k/ qualifies as /ŋ /, since, it depicts all the properties of the voiced velar consonant.

6.1.6 Phonetic Conclusion

Hence, in the light of the above discussion we are now in a fairly secure position to redefine the articulatory process involved in the utterance of the phonemes under study.

The procedure starts with the opening of the velopharyngeal port as is proved by the nasalization of the preceding vowel. This is followed by this nasal bands where the /ŋ/ is being uttered (the result of the glottal voicing escaping from the nasal cavity, proving the sound to be /ŋ / rather than /ŋ$_o$/) Then the nasal bands gradually weaken and then completely disappear illustrating the closure of the velopharyngeal port, and the end of /ŋ /. There follows a closure period (shorter for /g/ longer for /k/) in which pressure is developed in the velopharyngeal regions. This followed by a burst evident of the removal of the oral occlusion and any vowel following it is not nasalized.

Evidently, this procedure does not involve the articulation of a single phoneme (/ŋ / and /ŋ$_o$/) but two separate phonemes (that is /ŋ / /k/ and/ or /ŋ / /g/). Hence on acoustic grounds we can state that in Urdu /ŋ / does not exist independently, but it does exist. These are the cases where a /n/ is followed by a /k/ or a /g/ (i.e. a velar stop in general). The result is that /ŋ / is uttered first and then the burst is released to utter the respective velar stop. As the nasal bands never disappear from the spectrogram of /ŋ / hence there is no proof of the existence of the unvoiced velar nasal Inkma.

6.2 Phonological Inference

[3] Presents a very important study of nasal place assimilation, in which it is stated that the /n/ is articulated at the place of the stop which it precedes. Hence in case of bilabial stops /n/ becomes bilabial /m/, in case of dental /n/ becomes dental, and hence in case of velar stops /n/ becomes velar. If at this point the property of /n/ is scrutinized it is found to be velar, nasal (/n/ is nasal), stop. This exactly corresponds to the definition of /N /. Hence, when /n/, in Urdu, is followed by a velar stop it is converted into /N / followed by the respective stop. As far as velar stops are concerned our experiments show that this behavior is the result of the rule that Urdu speakers always tend to release stops.

Moreover, the minimal pair [bang] and [bank], exists as /b a N g/ and /b a N k/ in Urdu, with ingma preceding the velar stops. In addition, there is no phonological proof of Inkma as we are studying the nasal place assimilation of /n/ which is voiced and, hence, the ultimate amalgam also tends to remain so.

7. CONCLUSIONS

We started our journey with the dual aim of, verifying the existence of /ŋ / and, investigating the existence of Inkma, in Urdu. for this purpose we traced the steps of our predecessors to study the suspected regions of the spectrograms, but, on phonetic grounds we found concrete evidence, like the presence of the bursts of the velar consonants, the non nasal behavior of the following vowels, the independent existence of the nasal and velar phonemes, giving us firm grounds to prove that the portion of the spectrogram which is considered as the /ŋ/ does not qualify as the voiced, velar, nasal consonant that is /ŋ/. So, we started looking for alternate solutions. At last, a study of the portion of the spectrogram just before the bursts of the velar consonants, revealed that it contains all the qualities as required by /ŋ/ e.g. lack of burst, nasal murmur, voicing, high frequency anti-resonance patterns and murmur spectrum of high amplitude in low frequency regions. The phonological conclusion presented by [3] further strengthened our stand point.

Hence, we come to the conclusion that /ŋ/ only exists in Urdu where the voiced velar /n/ precedes a velar consonant. As such both /ŋ/ and the velar consonant co-exist. This behavior might be a result of the tendency of the Urdu speakers to release stops. In addition all our studies further reaffirms the already existing belief that there is no existence of an unvoiced, velar, nasal consonant in Urdu.

REFERENCES

[1] Pickett. J. M. *The Acoustics of Speech Communication.* Allyn and Bacon. 1999.

[2] Clark John and Yallop Colin. *An Introduction to Phonetics and Phonology.* Blackwell Publishers.1999.

[3] Syed Mustafa Shah. "Urdu nasal consonants and their phonological behavior". *Akhbar- e –Urdu.* Muqtadra Qaumi Zuban, Islamabad, Pakistan. April-May, 2002

[4] Kashif Munir and Tayyaba Mohsin. "Existence of ingma in urdu language and its phonological features". *Akhbar- e –Urdu.* Muqtadra Qaumi Zuban, Islamabad, Pakistan. June, 2003

[5] Ladefoged Peter and Maddieson Ian. *Sounds of World Languages.* Blackwell Publishers. 1999.

Appendix A (بانگ، بانک، بان، باگ، باک)

Appendix B یہ ـــــ ہے۔