

Palatalness and Palatalization of Sounds for Speech Therapists (Part 1)

Masaki TSUDZUKI

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1. Introduction

Regarding the principles of phonetic study, speech sounds are clarified on the basis of two bodies of evidence: perception evidence and physical evidence. Perception evidence derives from both the auditory impression and the articulatory sensation; physical evidence is gathered from both acoustic analysis and palatographic analyses.

That is, phonetic study should be based on the following approaches:

(1) Perception evidence:

(a) auditory impression

e.g. clear l [l] or dark l [ɫ]

(b) articulatory position

e.g. advanced [ɰ] or retracted [ɤ]

(2) Physical evidence:

(a) Acoustic Analysis (using the voice)

Sound-spectrographic Analysis

Visi-Pitch Analysis

Flow-Nasalitygraphic Analysis

(b) Palatographic Analysis (using articulators)

Traditional Palatography

Electro-palatographic Analysis

This article is mainly concerned with palatalness and palatalization. The focus first will be on making clear distinction between double articulation and coarticulation. Secondly, palatalness will be described. Thirdly, the mechanism of palatalization which is one of main members of secondary articulation will be explained. Fourthly, acoustic data will be shown to highlight the movements of the front of the tongue towards the hard plate and also partial or complete contact of two articulators using electro-palatograph.

IPA (The International Phonetic Alphabet) nominates seven phonetic symbols to denote palatals: such as voiced or voiceless palatal plosives [c], [j]; palatal nasal [ɲ]; voiced or voiceless palatal fricatives [ç], [ʝ]; palatal approximant [j] and voiced palatal lateral approximant [ʎ]. Many languages have consonants which are the same or similar either to these palatals of IPA or their variants. Some of them are involved in Japanese, such as; [ɲ], [ç] and [ʎ]. It is interesting to observe the articulatory mechanisms of these palatal sounds by highlighting with electro-palatographic data. The data are treated graphically considering the way of how data are visualized.

2. Double articulation or Coarticulation

Phoneticians have already explained *double articulation* and *coarticulation* fully which our languages have in their sound systems, so I need only briefly review these articulations in this section.

In Double articulation, two articulators of equal stricture are produced simultaneously at different places of articulation.

Coarticulation is the process by which the sequence of sounds is influenced by adjacent sounds or fused together into another single sound. In coarticulation, two articulations of different stricture are produced simultaneously at different places of articulation. The closest stricture of the two indicates the primary articulation while the more open indicates the secondary articulation. There are four main kinds of secondary articulations, such as labialization, pharyngealization, velarization and palatalization.

Coarticulation involves the two main factors; one is primary (dominant) articulation and the other is secondary (subsidiary) articulation. Secondary articulation occurs by producing the lesser degree of features accompanied with the primary articulation during articulatory movements.

W. J. Hardcastle, J. Laver, and F. E. Gibbon (324: 2010) explain the reason why coarticulation occurs as:

The function of coarticulation is to smooth out the differences between adjacent sounds; coarticulatory modifications accommodated the segments so that the transition between them are minimized.

There are two types of coarticulation. The one is anticipatory coarticulation and the other is regressive coarticulation.

Anticipatory coarticulation can be heard when a sound is influenced regressively anticipating the following sound's features with coarticulatory influence. The position or manner of articulations is altered

to a similar position or manner more like that of a following sound. In regressive coarticulation, the mechanism of the articulations is the opposite.

3. Articulatory palatalic mechanism

3.1. Palatalness

Palatal is a sound which is produced by touching or nearly touching between the front upper surface of the tongue and the hard palate. When a speech sound is pronounced by two articulators (the front of the tongue against the hard palate) in this way, we can call it as a consonant featuring *palatalness*.

Palatalness differs from *palatality* in the sense of definition by R. L. Trask. *Palatalness* is a typical articulatory feature which palatal has during production by touching or narrowing between the front of the tongue and the hard palate. According to R. L. Trask (254: 1996), *palatality* is described as follows:

A label commonly applied to the phonological prime { i } or I in various privative theories of phonology, especially Dependency Phonology.

Palatalness may occur, for example, in *ra*-series in a table of the Japanese syllabary, such as *rya* [ɽja], *ryo* [ɽjo] and *ryu* [ɽju] at the syllable initial, intervocalic and interconsonant positions. These [ɽ] are laterals with palatalness which can be transcribed as *rya* [ɽ^ja], *ryo* [ɽ^jo] and *ryu* [ɽ^ju]. Also in the *na*-series at the syllable initial and intervocalic and interconsonant positions; *nya* [nja], *nyo* [njo], *nju* [njɯ]. Words such as *kya* [kja], *sha* [ʃja], *cha* [tʃja], *mya* [mja] also have palatalness.

3.2. Palatalization

Palatalization is symbolized by [^j]. (small ^j at the upper right-hand corner of the phonetic symbol as [n^j])

R. L. Trask (254: 1996) gives an account of *palatalization* as follows:

The phenomenon in which a segment whose primary articulation is at some other location is articulated with a secondary articulation involving the raising of the front of the tongue towards the palate or (with back consonants) the moving of the constriction forward towards the palate.

Palatalization occurs by full or partial contact between the front of the tongue and the hard. In palatalization, the front of tongue has a wide approximation to hard palate ([i]-like or [j] position).

4. Acoustic Observation

4.1. Acoustical Achievements

In the late of the twentieth century, acoustical achievements have become the focus of phonetic studies. Acoustic phonetics has shown remarkable progress and has played an important role in analyzing perception and articulation of speech sounds. Acoustic phonetics clarifies the physical properties and features of speech sounds using an electric apparatus which are specially designed for phonetic investigation.

Phoneticians have contributed the progress and development of phonetic studies showing outstanding physical evidences. They have thrown new light on the issues of auditory and articulatory mechanism of the speech sounds using experimental apparatuses, such as sound spectrograph, electro-palatograph and flow-nazalitygraph, so on.

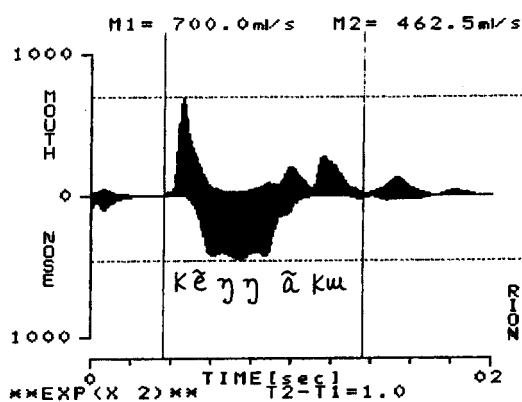


Fig. 1 Flow-nazalitygraphic Data: [kẽηōkũ] (nasalization by M. Tsudzuki)

4.2. Sound Spectrographic Data

4.2.1. Visible Speech

Phoneticians have offered reliable evidences through experimental methods in the fields of acoustic phonetics and speech perception. The sound spectrograph has been used for the past half century in speech research. The sound spectrograph, which was invented by R. K. Potter, G. A. Kopp and H. C. Green of Bell Telephone Laboratories (BTL), USA in the 1940's, has been one of the most useful and reliable devices for the study of speech sounds. It was originally intended as a visible speech aid for the hearing disabled people in speech disorders.

The sound spectrogram represented in *Visible Speech* by BTL was one of the most useful apparatuses used in a medical study as well as theoretical phonetics. It has enabled researchers to ascertain the physical characteristics of sounds and the physiological status of the speech organs by graphically representing sound frequencies. After their studies, numerous attempts have been made by phoneticians and linguists to demonstrate the formant features or patterns of vowels by sound spectrograph. This point deserves explicit emphasis.

4.2.2. Formants of the vowels

The original sound spectrograph was an analogue instrument based upon a variable frequency band pass filter and a display device that burned an image known as a spectrogram into a sheet of electro-carbon paper. Nowadays we can stably use the digital spectrogram obtained by a soft ware of the computer.

It is well known that the spectrograms which are produced by the sound spectrograph provide three visual evidences in which three important factors are illuminated; formant frequency vertically, time horizontally and intensity by the relative blackness or light and shade. Formants of the vowels representing on the sound spectrogram show the characteristic overtones of the sound in the production. The quality and attributes of a vowel are determined by the frequencies of the formants.

The formants of the vowel sounds represented on the sound spectrogram show the characteristic overtones of their actual sounds in production. The quality and attributes of a vowel are determined by the specific frequencies of their formants. Peter Ladefoged (1975) developed a formant chart which has been commonly used by phoneticians and linguists to analyze vowel qualities and compare the relationship between vowels as measured on a sound spectrogram. Ladefoged plots the frequency of the first formant on the ordinate (the vertical axis) and the difference between the frequencies of the first and the second formants on the abscissa (the horizontal axis). Ladefoged says (187: 1975) that the frequency of the first formant certainly shows the relative vowel height quite accurately. He further states that the distance between the first and the second formants reflects the degree of backness quite well, but that there may be confusion due to variations in the degree of lip rounding.

4.2.3. Sound spectrographic data of approximant [j]

It is easily understood that coarticulation effects effectively modifies the point of constriction of approximant [j] in connected speech. However, in respect to sound spectrographic data of the sound sequences (consonants + [j] + vowels), as far as the writer concerns, there are not enough examples and explanations. For example, W. J. Hardacastle, J. Laver, and F. E. Gibbon (100: 2010) say that [j] like [i]

has a low F1 and a high F2. Shigeru Takebayashi (77–78: 1996) highlights Japanese and English words including [j] by demonstrating sound spectrographic data.

The following are data using the writer's pronunciation. Phonetic transcriptions, such as [ɰj], [ɰj], [kj], [ɕj], [tɕj] and [mj] may be substituted tentatively by other phonetic symbols, such as [ʌʝ], [ɰʝ], [kʝ], [ɕʝ], [tɕʝ] and [mʝ]. Some of the commonest Japanese words containing these are: *kyoryoku*, *nyugaku*, *shuryo*, *Kyushu*, etc.

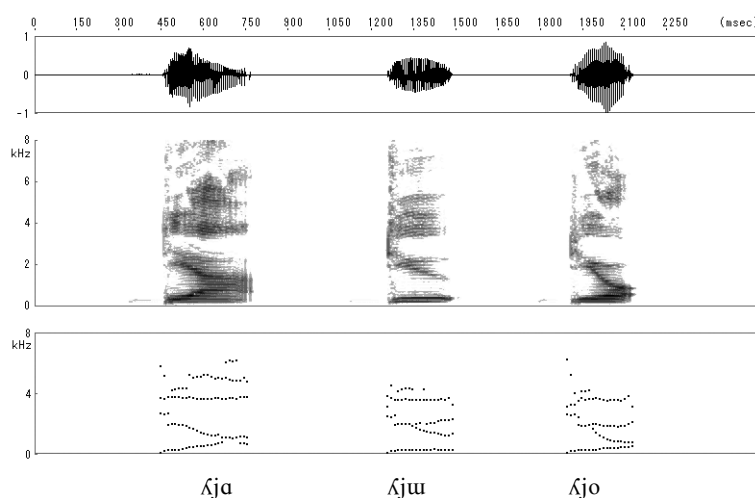


Fig. 2

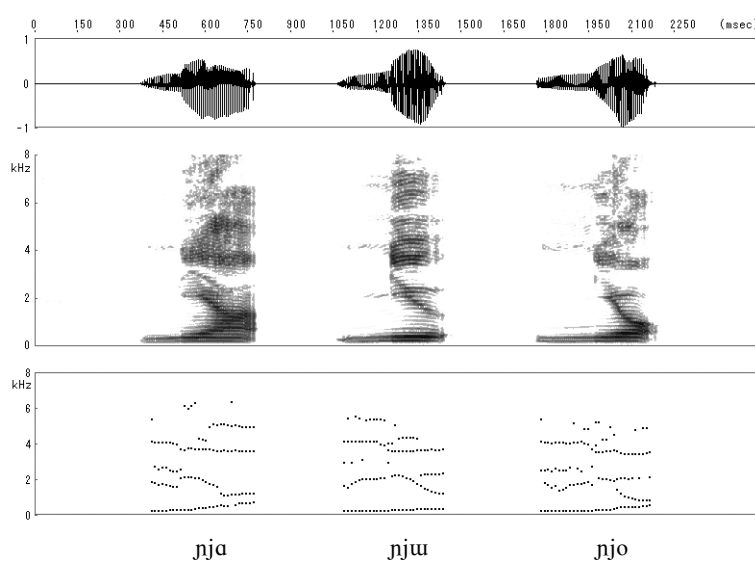


Fig. 3

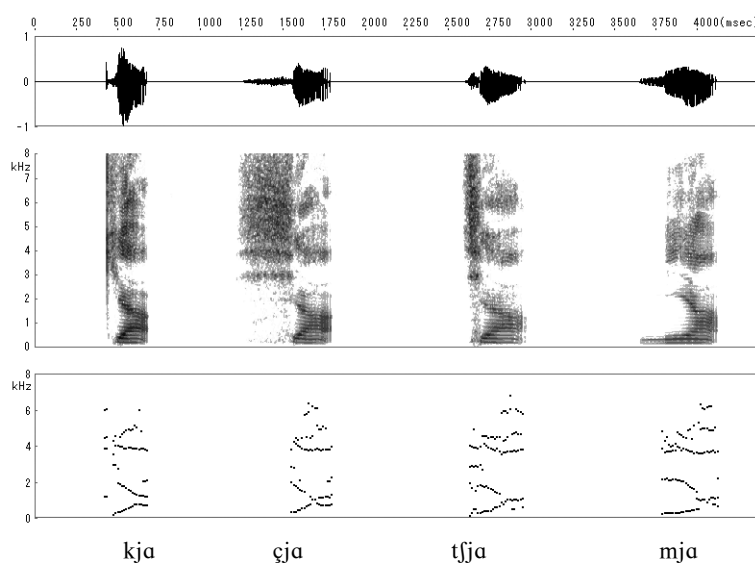


Fig. 4

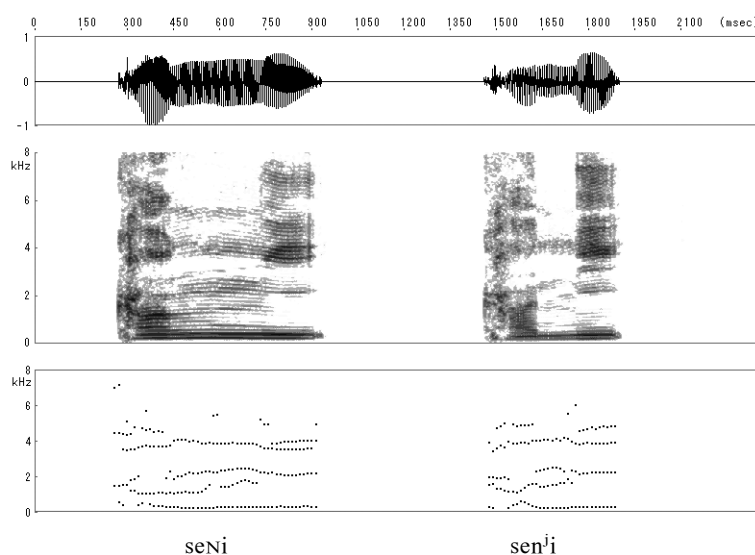


Fig. 5

(Figures No. 2, No. 3, No. 4 and No. 5 are pronounced by M. Tsudzuki)

4.3. Traditional palatograph

4.3.1. Powder *wipe-off* type

Palatograph had been a standard technique in studying tongue-palate contacts during speech

articulation. In a classical palatograph, the subject's palate is painted with some powdery material. The *wipe-off* of the powder on the palate, corresponding to areas of contact by the tongue, is observed after a given articulatory gesture. The palatogram thus obtained, however, gives rather static information about the total area where the tongue contact took place at least once throughout the time course of the gesture.

Before the electro-palatograph was invented, a traditional palatograph were reported to show various phonetic analyses by D. Jones (1964) and A. C. Gimson & A. Cruttenden (1994). Those artificial palatographs show articulatory tongue positions of *alveolar*, *post-alveolar* and *palatal consonants*.

The traditional palatograph can show the point of articulation upon the artificial palate which has been placed upon the inside of the upper jaw. Historically, the palatogram was first experimented by Oakley Coles in 1871. After that D. Jones's palatogram is useful and helpful for practical purposes; however, we can only see this tongue-palate action represented statically rather than in its real, kinetic state.

D. Jones (§.656, Figs. 77, 78: 172: 1978) shows two palatograms, one is the *advanced* [ŋ] in the English sequence [-iŋ] and the other is the French [ɲ] in the sequence [aɲa].

R. L. Trask (255: 1996) describes a palatography as follows:

A technique for determining which areas of the roof of the mouth are touched by the tongue during an articulation. Either the roof of the mouth is coated with a coloured material, or a false palate similarly coated is inserted into the mouth; after the articulation of interest is performed, the mouth or false palate is examined to see where the coating has been removed.

According to the account of *linguagram* by R. L. Trask (208: 1996), it is described as:

A photograph of the tongue showing which parts of it have been coloured by contact with the colouring matter applied to the roof of the mouth during a traditional kind of palatography.

4.3.2. Tongue-palate contacted mechanism

We can see the static contact areas or palatalization made by speech organs or articulators in the mouth using the traditional palatograph. The articulatory contact conditions between upper lip and lower lip, or upper teeth and lower lip, movement of the uvular, velarization, so on, cannot be observed.

4.4. Electro-palatograph

4.4.1. Three versions of electro-palatograph

Fiona Gibbon and Katerina Nicolaidis (229–230: 1999) make an account that there are three commercially available versions of EPG in current use as briefly cited here: A British system developed

at the University of Reading (the latest version being the Reading EPG3 system; a Japanese system manufactured by the Rion Corporation (the Rion DP01), and an American Palatometer marketed by Kay Electric corporation. And F. Gibbon and K. Nicolaidis describe as follows: All three systems share some general features, but differ in details such as the construction of the palates, number and configuration of electrodes and hardware/software specifications.

4.4.2. Purpose of the electro-palatograph

The first purpose of the electro-palatograph is to visually observe the articulation in functional tests for patients suffering from articulation disorders caused by hearing disabilities, cerebral palsy or structural disorders of the hard palate. Secondly, such data is also applied to phonetic research. The electro-palatograph is useful and helpful not only for the patient with speech disorders but also for the person who wants to learn the correct pronunciation of his or her mother tongue or a foreign language.

Electro-palatograph or dynamic palatograph as it is sometimes called, has been used efficiently for analyzing statistic or kinetic tongue palate contacts with the hard palate during sound production.

In respect to the definition of the continuous palatography, R. L. Trask (91: 1996) makes an accurate account as:

A variety of palatography involving a false palate with electrodes implanted, allowing palatal contact to be recorded continuously over time during a series of articulations.

Trask (129: 1996) also mentions on electro-palatography as:

a version of palatography using a false palate implanted with electrodes, so that contact between the tongue and the roof of the mouth may be continuously recorded and displayed. The instrument is an electro-palatograph; the output is an electro-palatogram.

4.4.3. Electro-palatographic data by phoneticians

It is believed that the analysis or signification by the use of the electro-palatographic data presented by professors, Hyun Bok Lee and Hiroyuki Umeda have given impetus to further study in this hitherto unexplored field of Comparative-Acoustic Phonetics.

One well known investigation by electro-palatograph was done by Lee, H. B. (1-47: 1980) in which he studied Korean consonants such as plosive, affricate, lateral and nasal. Retroflexion and palatalization in Korean sounds were reported in his paper. His was the first article published in Korea in which electro-palatographic data was featured. In that paper he showed nearly 90 intricate palatograms and clarified the

actual realization of those consonants.

Gimson's works, *An Introduction to the Pronunciation of English*, was first published 1962 and was revised by Alan Cruttenden as *Gimson's Pronunciation of English*, 1994. In the present version, palatograms newly appear. In *Foreword to the Fifth Edition* (1994) of the new version, A. Cruttenden writes that the palatogram are offered by Martin Barry.

4.5. Rion's electro-palatograph

4.5.1. Methodology of using electro-palatograph

In order to examine the kinetic or dynamic conditions of the tongue-palate contacts, an electro-palatograph has been devised by Rion Co. The electro-palatograph was originally devised for observing kinetic conditions of tongue-palate contact by Rion Co. in the late 1960's. It represents the quick-moving conditions of tongue-palate contact on the horseshoe palatogram. The electro-palatograph invented by Rion Co. is not only an intricate piece of machinery but also a delicate mechanism.

Experiments have been carried out by using speech materials of the author. The period of experimentation using sound spectrograph and electro-palatograph was from 8th January, 2001 to 18th September, 2003.

The phonetic symbols used throughout this thesis are those of the I.P.A. (2002); *The Principles of the International Phonetic Association*, University College, London.

4.5.2. Artificial palate

In order to get a well fitted electro-palatograph for the subject, as the first stage, the researcher's own electro-palatograph has to be made of his or her dental impression. So it is necessary to have a plaster cast of the teeth (teeth impression) made at a dental office in advance. As the second stage, the sixty three metallic electrodes are implanted in a thin artificial palate which was made to fit the hard palate of the subject. Each electrode is 1 mm in diameter and is attached to a fine insulated wire. The wires are gathered and inserted into a vinyl tube which leads out from the mouth to the computer.

4.5.3. Mechanism and usefulness

We can observe the tongue-palate contact (touching area) or movements of the tongue (kinetic condition) against the hard palate by the sixty three electric signals on the real-time monitor screen or slow-motion picture. Each electro-palatogram is shown in the horse's hoof-shaped frame.

In the horse's hoof-shaped frame of the electro-palatogram, lingual contacts are represented by [+]

and non-contacts by [·]. Each representation of the electric signal ([+] or [·]) on the screen is arranged in the position corresponding to each of the electrodes implanted on the electro-palatograph. The data can be automatically stored on a floppy disk for repeated display. The Rion's electro-palatograph can produce sixty horse's hoof-shaped frames per second of the electro-palatogram.

4.5.4. Drawback

The electro-palatograph invented by the Rion has sixty three metallic electrodes implanted into the thin artificial palate made to fit the hard palate of the subject. Electric signals displayed on the real time computer screen make it possible for researchers to observe not only tongue-palate static contacts but also kinetic tongue movements. However, through phonetic laboratory works, the writer understands the mechanical limitations which electro-palatograph has and agrees the following account by W. J. Hardacastle, J. Lver, and F. E. Gibbon (30: 2010):

The drawback of EPG is that data are collected only when the tongue touches the palate. Thus information is lost when the jaw lowers the tongue away from the domain of the palate, as occurs during mid and low vowels. However, during continuous speech the tongue is in fairly continuous contact with the palate at one location or another. EPG thus contributes greatly to the study of speech, especially the study of lingual consonants, constriction shapes and sizes, increasing its value in studies of language and disorders.

4.5.5. Tsudzuki's electro-palatographic system

The writer established his methodology of analysing Rion's EPG (DP-20). At each frame of the electro-palatogram, 63 points which can represent either contacted or non-contacted electrodes are numbered by the writer as follows:

First Outer Circle, Left: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 2LA.

Second Outer Circle, Left: 13LB, 11LB, 9LB, 8LB, 6LB, 5LB, 4LB.

Third Outer Circle, Left: 13LC, 11LC, 9LC, 8LC, 7LC, 6LC.

Second Inner Circle, Left: 13LD, 11LD, 9LD, 8LD.

First Inner Circle, Left: 14LE, 12LE, 10LE.

Central or Middle Line: 1M, 4M, 6M, 7M, 9M, 11M, 13M.

First Inner Circle, Right: 14RE, 12RE, 10RE.

Second Inner Circle, Right: 13RD, 11RD, 9RD, 8RD.

Third Outer Circle, Right: 13RC, 11RC, 9RC, 8RC, 7RC, 6RC.

Second Outer Circle, Right: 13RB, 11RB, 9RB, 8RB, 6RB, 5RB, 4RB.

First Outer circle, Right: 13RA, 11RA, 9RA, 8RA, 6RA, 4RA, 3RA, 2RA.

The writer's numbering system of the electrodes on the palatogram and the correspondence of electrodes to the upper articulatory locations were shown in his previous papers (2002, 2003 and 2005).

5. Japanese alveolar nasal with palatalness

5.1. Five variants of nasals

Japanese obviously contains five variants of nasal, such as, [m], [n], [ɲ], [ŋ], and [ɳ] which are mainly conditioned by the following sounds or sound circumstances. A retroflex nasal [ɳ] is not included among them. In producing the uvular nasal, the out-going air current can be allowed to escape through the nose as well as through the mouth by lowering the uvula. The Japanese uvular nasal tends to be a velar nasal in the syllable-final position because of the reduction of articulatory energy.

In respect to alveolar nasal, it is assumed by articulatory observation that the point of articulation of the [n] is influenced to a certain degree by the adjacent vowel quality. And this point will be argued by showing using electro-palatograms. Incidentally, [ɳ] also occurs in the Inuit language (O'Connor: 1982).

5.2. Electro-palatographic observation of *ni* [ni]

An alveolar nasal has been experimented by the electro-palatograph. To summarize, in the case of [n] in [ni], the blade, front and sides of the tongue make wide contact with the palate. The [n] in [ni] has great palatalness and can be transcribed as [n^j]. The maximum tongue-palate contact in [ni] has 61 contacted electrodes or 96.825 % of the total. Complete closure continues for a succession of 16 frames with the duration of 0.250 seconds. The average number of contacted electrodes of the three stages; at the first, the maximum and final complete closure (Fig. 6), is 52 or 82.539 % of the total. Palatalness occurs greatly in [n^j].

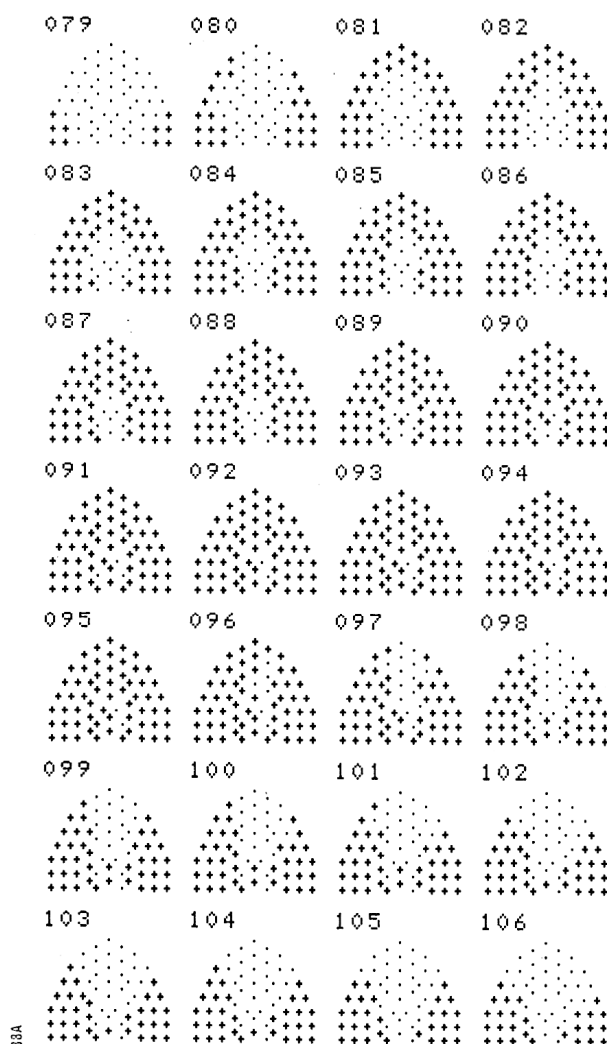


Fig. 6 Complete tongue-palate closure of [n^j] ([ni] with great palatalness, M. Tsudzuki)

5.3. Electro-palatographic observation

5.3.1. [n] in *ana* [ana] (with no palatalness)

At the first stage of production, the tip and sides of the tongue make a fine or narrow contact with the palate. Tongue-palate contact occurs completely at the first outer circle and partially at the second outer circle. Complete closure begins at frame No. 092 which has 26 contacted electrodes or 41.269% of the total: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 2LA, 1M, 13RA, 11RA, 9RA, 8RA, 6RA, 4RA,

3RA, 2RA, 13LB, 11LB, 4M, 13RB, 11RB, 8RB, 6RB, 5RB, 4RB. Maximum tongue-palate contact occurs at frames Nos. 095–098. In each frame there are 44 contacted electrodes or 69.841% of the total: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 2LA, 1M, 13RA, 11RA, 9RA, 8RA, 6RA, 4RA, 3RA, 2RA, 13LB, 11LB, 9LB, 8LB, 6LB, 5LB, 4LB, 4M, 13RB, 11RB, 9RB, 8RB, 6RB, 5RB, 4RB, 13LC, 11LC, 9LC, 8LC, 7LC, 6LC, 13RC, 11RC, 9RC, 8RC, 7RC, 6RC. The final complete closure occurs at frame No. 100 which has 30 contacted electrodes or 47.619% of the total: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 2LA, 1M, 13RA, 11RA, 9RA, 8RA, 6RA, 4RA, 3RA, 2RA, 13LB, 11LB, 9LB, 8LB, 6LB, 5LB, 4LB, 4M, 13RB, 11RB, 5RB, 13LC, 11LC. Complete tongue-palate closure begins at frame No. 092 and continues to frame No. 100. Complete closure continues for a succession of 9 frames with a duration of 0.140 seconds. After the break of the last closure, there remains a wide air passage (e.g., frames Nos. 102–103). The average number of contacted electrodes of the three stages (at the first, the maximum and final complete closure) is 33 or 52.381% of the total. Maximum tongue-palate contact occurs at frame No. 095 and continues to frame No. 098 for a succession of 4 frames over a duration of 0.062 seconds. The author's palatogram shows that the intervocalic [n] in *ana* [ana] is realized as *an alveolar nasal* [n].

5.3.2. [n] in *ini* [ini] (with palatalness)

At the first stage of production, the tip and sides of the tongue make wide contact with the palate. Tongue-palate contact occurs at the first, second and third outer circles. Complete closure begins at frame No. 079 which has 48 contacted electrodes or 76.190% of the total: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 13RA, 11RA, 9RA, 8RA, 6RA, 4RA, 3RA, 13LB, 11LB, 9LB, 8LB, 6LB, 5LB, 4M, 13RB, 11RB, 9RB, 8RB, 6RB, 5RB, 4RB, 13LC, 11LC, 9LC, 8LC, 7LC, 6LC, 6M, 13RC, 11RC, 9RC, 8RC, 7RC, 13LD, 11LD, 9LD, 8LD, 13RD, 11RD, 9RD, 14RE. Maximum tongue-palate contact occurs at frames No. 082 and No. 083. In each frame there are 57 contacted electrodes or 90.476% of the total. At frame No. 082: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 2LA, 1M, 13RA, 11RA, 9RA, 8RA, 6RA, 4RA, 3RA, 2RA, 13LB, 11LB, 9LB, 8LB, 6LB, 5LB, 4LB, 4M, 13RB, 11RB, 9RB, 8RB, 6RB, 5RB, 4RB, 13LC, 11LC, 9LC, 8LC, 7LC, 6LC, 6M, 13RC, 11RC, 9RC, 8RC, 7RC, 6RC, 13LD, 11LD, 9LD, 8LD, 13RD, 11RD, 9RD, 14LE, 14RE, 12RE, 11M, 13M. At frame No. 083: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 2LA, 1M, 13RA, 11RA, 9RA, 8RA, 6RA, 4RA, 3RA, 2RA, 13LB, 11LB, 9LB, 8LB, 6LB, 5LB, 4LB, 4M, 13RB, 11RB, 9RB, 8RB, 6RB, 5RB, 4RB, 13LC, 11LC, 9LC, 8LC, 7LC, 6LC, 6M, 13RC, 11RC, 9RC, 8RC, 7RC, 6RC, 13LD, 11LD, 9LD, 8LD, 13RD, 11RD, 9RD, 14LE, 9M, 14RE, 11M, 13M. At the final complete closure (frame No. 087), there are 39 contacted electrodes or 61.904% of the total: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 13RA, 11RA, 9RA, 8RA, 6RA, 4RA, 13LB, 11LB, 9LB, 8LB, 6LB,

13RB, 11RB, 9RB, 8RB, 6RB, 13LC, 11LC, 9LC, 8LC, 7LC, 13RC, 11RC, 9RC, 8RC, 13LD, 11LD, 9LD, 13RD, 11RD, 14LE, 11M. Complete tongue-palate closure begins at frame No. 079 and continues to frame No. 087. Complete closure continues for a succession of 9 frames with a duration of 0.140 seconds. After the break of the last complete closure, there remains wide tongue-palate contact at both sides of the palatogram (e.g., frames Nos. 088–094). The average number of contacted electrodes of the three stages (at the first, the maximum and final complete closure) is 48 or 76.190% of the total. Maximum tongue-palate contact occurs at frame No. 082 and continues to frame No. 083 for a succession of 2 frames over a duration of 0.031 seconds. Palatalization occurs greatly in [n] conditioned by the adjacent vowel [i] which hems [n] in the combination of [inⁱ] (e.g., frame No. 083). It is shown by the author's electro-palatogram that the Japanese inter-vocalic [nⁱ] in *ini* [inⁱ] has great palatalness.

5.3.3. [ɲ] in *nyu* [ɲju] (with palatalness)

In the pronunciation of [ɲju], the first complete tongue-palate closure occurs on the front and sides of the palate at frame No. 025. In that frame, there are 47 contacted electrodes or 74.603% of the total: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 13RA, 11RA, 9RA, 8RA, 6RA, 4RA, 13LB, 11LB, 9LB, 8LB, 6LB, 5LB, 4LB, 4M, 13RB, 11RB, 9RB, 8RB, 6RB, 5RB, 4RB, 13LC, 11LC, 9LC, 8LC, 7LC, 6LC, 6M, 13RC, 11RC, 9RC, 8RC, 7RC, 6RC, 13LD, 11LD, 9LD, 8LD, 13RD, 11RD. Maximum tongue-palate contact occurs at frames Nos. 030–040. In each frame there are 63 contacted electrodes or 100% of the total: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 2LA, 1M, 13RA, 11RA, 9RA, 8RA, 6RA, 4RA, 3RA, 2RA, 13LB, 11LB, 9LB, 8LB, 6LB, 5LB, 4LB, 4M, 13RB, 11RB, 9RB, 8RB, 6RB, 5RB, 4RB, 13LC, 11LC, 9LC, 8LC, 7LC, 6LC, 6M, 13RC, 11RC, 9RC, 8RC, 7RC, 6RC, 13LD, 11LD, 9LD, 8LD, 7M, 13RD, 11RD, 9RD, 8RD, 14LE, 12LE, 10LE, 9M, 14RE, 12RE, 10RE, 11M, 13M. At maximum tongue-palate contact, all parts of the palate are completely contacted. That is, the front of the tongue is fully raised towards the hard palate, because of the influence of the following [j]. Complete tongue-palate closure starts from frame No. 025 and continues to frame No. 044, a succession of 20 frames, for a duration of 0.312 seconds. The last complete closure occurs at frame No. 044. There are 47 contacted electrodes or 74.603% of the total: 13LA, 11LA, 9LA, 8LA, 6LA, 4LA, 3LA, 13RA, 11RA, 9RA, 8RA, 6RA, 4RA, 13LB, 11LB, 9LB, 8LB, 6LB, 5LB, 13RB, 11RB, 9RB, 8RB, 6RB, 13LC, 11LC, 9LC, 8LC, 7LC, 6LC, 13RC, 11RC, 9RC, 8RC, 7RC, 13LD, 11LD, 9LD, 8LD, 13RD, 11RD, 14LE, 12LE, 10LE, 14RE, 11M, 13M. The average number of contacted electrodes of the three stages (at the first, the maximum and final complete closure) is 52 or 82.539% of the total. The number of frames of maximum tongue-palate contact is 11 frames (frames Nos. 030–040) or 0.171 seconds. There occurs great palatalness during the

pronunciation of [ɲ] in *nyu* [ɲju].

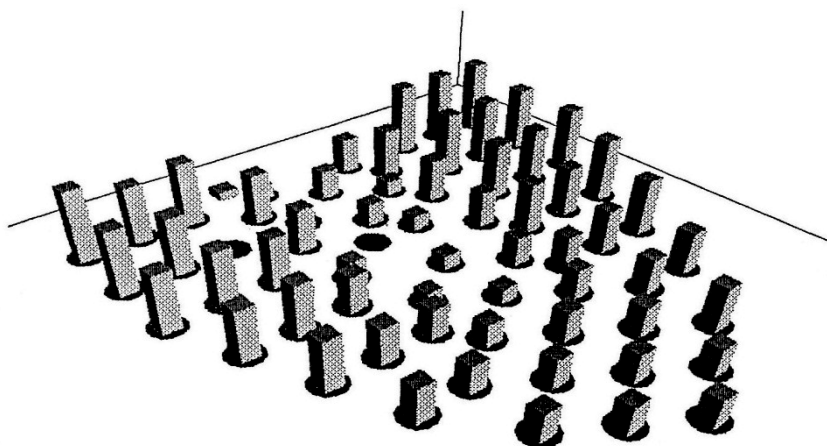


Fig. 7 The illustration of [ɲ] with palatalness (M. Tsudzuki)

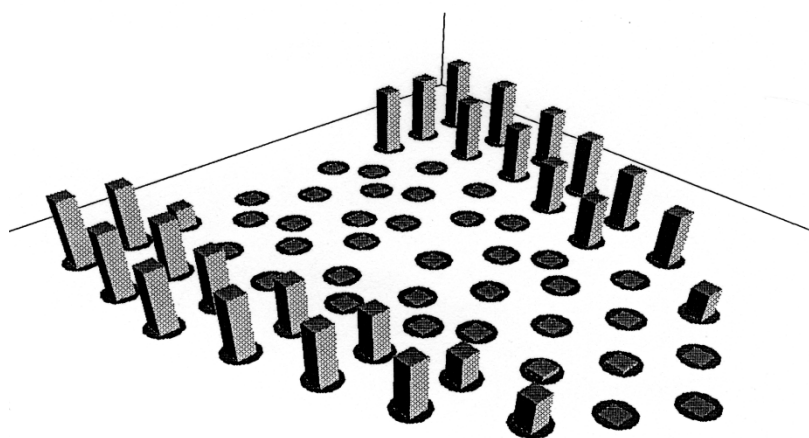


Fig. 8 The illustration of uvular nasal [ɴ] of *insa* [ɪɴsa] (M. Tsudzuki)

Fig. 8 is the illustration of producing the uvular nasal which shows the out-going air current through the mouth without blocking during the production of the word *insa* [ɪɴsa]. These tongue-palate mechanism are easily understood if we compare [ɲ] and [ɴ] graphically.

Conclusion

In the late of the twentieth century, acoustical achievements have become the focus of phonetic studies. Acoustic phonetics has shown remarkable progress and has played an important role in analyzing perception and articulation of speech sounds. Phoneticians have contributed the progress and development of phonetic studies showing outstanding physical evidences. They have thrown new light on the issues of auditory and articulatory mechanism of the speech sounds using experimental apparatuses, such as sound-spectrograph (SPG), electro-palatograph (EPG) and flow-nazalitygraph (FNG), so on.

The writer's research on speech sounds has been developed along articulatory and experimental lines, using the sound spectrograph, electro-palatograph and flow-nazalitygraph. His contribution to the field has been to establish three fundamental methodologies for the study of speech-sounds based on: auditory perception, articulatory feeling as reported by the articulator and physical evidence such as acoustic and palatographic analysis. The observations of the dynamic changes of tongue-palate contact were established using Rion's electro-palatogram.

In this article (Part 1), the actual realization of the alveolar or palatal nasal in the context *ni* [ni], *ini* [ini] and *nyu* [njɯ] are examined by considering the electro-palatographic data of the *horse's hoof-shaped* frame and also examining the articulatory feeling and auditory impression. And it is clarified that [n^ji], [in^ji] occur featuring with palatalness. To summarize, a Japanese alveolar nasal is realized as a *horse-shoe* type of the electro-palatogram and moraic uvular nasal can be seen in the *butterfly* type frame. This idea is easily recognized when highlighting electro-palatogram graphically.

(To be continued)

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