

States of the Glottis of Thai Voiceless Stops and Affricates

Jimmy G. Harris

University of Victoria*

INTRODUCTION

Ellis (1869–1889, pp. 1097–1111) and Sweet (1877, pp. 74–75) gave us excellent early European descriptions of the states of the glottis during the different phases of the articulatory stricture of stops. They identified three different phases of an articulatory stricture and called them the on-glide phase, the consonant phase, and the off-glide phase. In this century, Abercrombie (1967, p. 140) and Laver (1994, p. 133) have given us good descriptions of the three phases of a stop. Laver clearly described an additional overlapping phase covering both the release (or offset) phase of an initial consonant and the shutting (or onset) phase of an immediately following vowel. These four phases of an articulatory stricture are frequently called 1.) the shutting (or onset) phase; 2.) the closure (or stricture) phase; 3.) the release (or offset) phase, and 4.) the overlap phase. In this study of the states of the glottis of Standard Thai voiceless stops and affricates my primary focus is on observations of the state of the glottis during the articulatory strictures.

Holder (1669, pp. 30–31) very early made a clear distinction between two states of the glottis: breath and breath vocalized (voice). Sweet (1877, p. 75), unfortunately, used voiceless as an alternate for breath, which has led to confusion, since several states of the glottis are voiceless. I prefer to use *voiceless* as a cover term meaning ‘without voice,’ which allows us to divide the sounds of the world’s languages into those with voice (voiced) and those without voice (voiceless), while reserving the term *breath* for a particular voiceless state of the glottis. Catford (1968, p. 319) states that breath and nil phonation are the voiceless phonation types. He defined both breath and nil phonation as produced with a wide open glottis but with a difference in the turbulence of the airflow through the wide open glottis. He stated that the breathed [breθt] state of the glottis has a turbulent airflow through the wide open glottis as in audible breathing and the nil phonation state of the glottis has a non-turbulent airflow through a wide open glottis as in silent breathing. Later Catford (1990, p. 26) described an unphonated state of the glottis as made with either a closed glottis or no air passing through the glottis. Voiceless glottal stops, ejectives, and clicks can thus be said to be unphonated. Recently, Catford (personal communication) stated that he is inclined to believe that neither the nil phonation state of the glottis nor the unphonated state of the glottis is appropriate for describing the state of the glottis used during the closure phase of the articulatory stricture of the voiceless unaspirated oral stops. I totally agree and feel that Catford’s (1964, 1968, 1990) definitions of the breath state of the glottis, the nil phonation state of the glottis, and the unphonated state of the glottis are all equally inappropriate for describing the state of the glottis used during the closure phase of the articulatory stricture of an initial voiceless unaspirated oral stop. Sweet

* Researcher.

(1877, p. 74) stated that in the production of a voiceless unaspirated oral stop with a voiced offglide the glottis is in the position for voice during the stop, but without any air being forced through it. Catford (1977, pp. 114–115) states that voiceless unaspirated oral stops have a narrowed (though not completely closed) glottis that is restricted in a cross sectional area and that voiceless aspirated oral stops have a more or less widely open glottis. From fiberoptic studies done at the University of Edinburgh in 1977, using a native speaker of Bangkok Thai, it became clear to me that the state of the glottis for initial voiceless unaspirated oral stops and the state of the glottis for initial voiceless aspirated oral stops were not both open breath states of the glottis.

Holder (1669, pp. 60, 72) defined a glottal stop as ‘a stop made in the larynx.’ Others, such as Laver (1994, pp. 187–188), have defined it as a maintained glottal closure. Still others, such as Noël-Armfield (1931, p. 107), Heffner (1950, p. 125), Gleason (1955, p. 189), and Jones (1956, p. 19), have defined glottal stop as a closure and opening of the glottis. Jones also added that the glottis must be tightly closed. Sweet (1877, 1906) defined glottal stop as an ordinary cough or the sudden shutting and opening of the glottis, as in a cough. His analogy to a cough may be closer to reality. An ordinary cough is not simply suddenly closing and opening the vocal folds without other constrictions within the supraglottal cavity. There can be quite a bit of supraglottal cavity constriction in an ordinary cough. Glottal stop, up to the present day, is frequently defined simply as a closed or tightly closed glottis without any reference to the ventricular folds, arytenoid cartilages, or supraglottal cavity activities. However, as we will see, either “closed glottis” or “tightly closed glottis” is neither a detailed nor a complete description of the Standard Thai final glottal stop in [tɔ̌ʔ] ‘table.’ A more complete description of glottal stop will be given below.

VOICELESS STATES OF THE GLOTTIS

There are three voiceless states of the glottis used in the production of Standard Thai voiceless stops and affricates. They are *breath*, *prephonation*, and *unphonated*. The breathed state of the glottis is used in the production of the Thai initial voiceless aspirated oral stops and affricates [ph, th, kh, tch] and the initial [h]. The prephonation state of the glottis is used in the production of the initial Thai voiceless unaspirated oral stops and affricates [p, t, k, tc]. The initial glottal stop, represented by ๑ in the Thai orthography, is in normal non-emphatic conversation not a glottal stop at all. It is most frequently simply a prephonation state of the glottis forming a zero initial onset to a word initial vowel. The unphonated state of the glottis is used in the production of the Thai unreleased final voiceless simultaneous glottal + oral stops [ʔp, ʔt, ʔk] and the final glottal stop [ʔ] in short stressed syllables.

The photographs in Figure 1 are single-frame excerpts of the state of the glottis during the articulatory stricture of Cardinal Consonant pronunciations of initial voiceless aspirated oral stops, initial voiceless unaspirated oral stops, final voiceless unreleased glottal + oral stop double articulations, and final glottal stop in a short stressed syllable. The composite drawings below the photographs were derived from numerous photographs of the three voiceless states of the glottis in several languages including Standard Thai and Cantonese. Both the photographs and the drawings clearly represent the norm for the three voiceless states of the glottis of Standard Thai.

The top of each photograph and drawing in Figure 1 depicts the anterior portion of the laryngeal cavity and the bottom, the posterior portion of the laryngeal cavity.

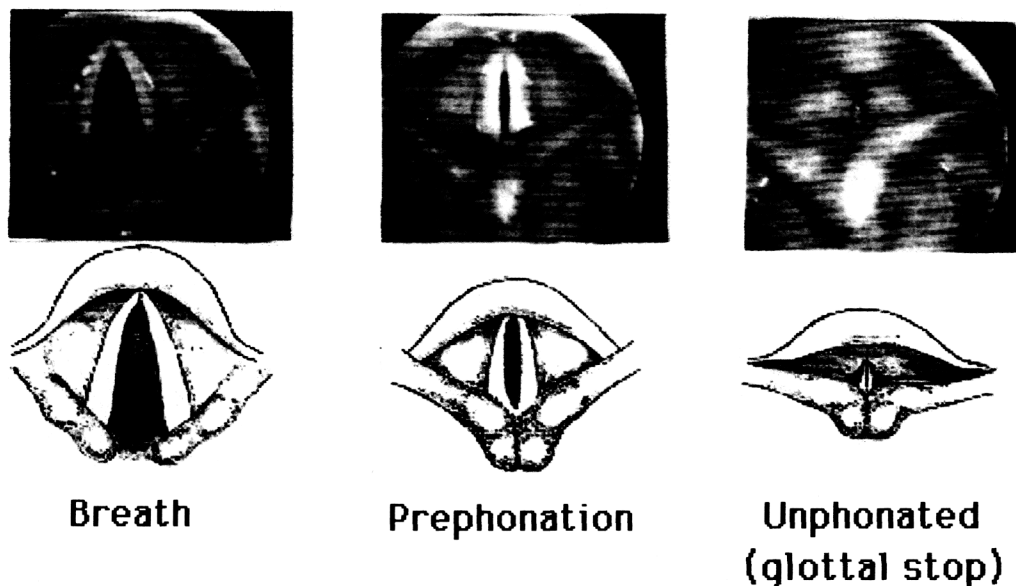


Figure 1. Photographs and drawings of three voiceless states of the glottis.

In the breathed state of the glottis in Figure 1 the vocal folds, ventricular folds, and arytenoids are widely abducted but not to the extent of forced inhalation. In forced inhalation the glottis and arytenoids can reach their maximum width of two or more times the width in a breathed state of the glottis. The breathed state of the glottis is characterized by a slightly turbulent airstream through a widely abducted glottis and arytenoid cartilages. Also in the breathed state of the glottis, the degree of aspiration can influence the width of the glottal opening and the width of the arytenoid cartilages' opening. The heavier the aspiration the wider open they are. During heavy aspiration in stressed syllables they can approximate the state of glottis for forced exhalation. There are two major differences between forced inhalation, forced exhalation, breath, and prephonation. First, only in the prephonation state of the glottis are the arytenoid cartilages adducted as for modal voice, and the vocal folds form a narrowed convex-convex opening medially in the glottis. Second, in the prephonation state of the glottis there seems to be insufficient subglottal air pressure during the closure phase of the articulatory stricture to initiate an airflow through the glottis. An airflow through the partially open glottis does not appear to be initiated until during the release phase of the consonant and the overlapping onset phase of the following vowel, when the subglottal air pressure increases and a small amount of air flows through the narrowed glottis at a higher rate of speed. This small amount of air is used to initiate the first stage of the glottal cycles of voice and produces a predictable small amount of Voice Onset Time lag before the full voicing cycles of the following vowel are reached. The rapid airflow through the glottis and the elasticity of the vocal fold tissue with the resulting Bernoulli effect cause a negative pressure between the medial edges of the vocal folds that sucks them together, initiating the vibratory movements of the vocal

folds being sucked together and blown apart at a very rapid rate, thus initiating the full voicing cycles of the following vowel. The unphonated state of the glottis for final glottal stop and oral + glottal double stop articulations clearly shows the complete adduction of the vocal folds but also the partial adduction of the ventricular folds. Although the partial adduction of the ventricular folds reinforcing the glottal closure may vary in the degree of adduction it was, in my observations, never completely absent. It appears to be an important component of both the Thai final glottal stop in short stressed syllables and the Thai final unreleased oral + glottal double stop articulations [ʔp], [ʔt], and [ʔk].

STANDARD THAI ORTHOGRAPHY AND GLOTTAL STOP

The modern Standard Thai script is of Indic origin, as are all non-Chinese or non-Roman scripts of Southeast Asia. In the original Indic script called Brahmi, as in all the Southeast Asian scripts derived from it, the system is basically a syllabic consonant system. In this type of system a written consonant symbol is followed by an unwritten inherent vowel which is usually [a]. What is important to our discussion here, is the fact that this kind of syllabic alphabet cannot have an initial vowel. So for example, in the Standard Thai word ๑๑ 'younger paternal uncle or aunt,' ๑ represents a historical glottal stop that is no longer phonetically there, and ๑ represents the long vowel [a:], which is the only sound heard in an unemphatic pronunciation of the word. An important part of the historical reconstruction of Ancient Tai is based on the Thai script and the existence historically of initial prevocalic glottal stops, preglottalized approximants, and preglottalized voiced stops (or preglottalized voiced nasals) such as *ʔa, *ʔi, *ʔj, *ʔw, *ʔd, and *ʔn. Today only the preglottalized vowels and a few examples of the preglottalized approximant ๑๑ [*ʔj], are still reflected in the spelling of Standard Thai.

There are, presently, two symbols in written Standard Thai used to represent glottal stop. Written Thai ๑ is used for the initial mute "glottal stop," and ๑ is used for a final true glottal stop. Danvivathana (1987, pp. 69–70) states that in the early Sukhothai and King Li Thai scripts of the 13th and 14th centuries, three of the functions of an inverted ancestral form of ๑ were: (1) it represented aʔ when used alone in a stressed syllable, as in ๑๑ [pàʔ] 'to patch'; (2) it represented glottal stop after other stressed short vowels; and (3) it was occasionally used after syllable final unaspirated stops. Did it represent final double stop articulations [ʔp], [ʔt], and [ʔk], as Danvivathana seems to imply? If it did, the scribe was a very good phonetician for his time. De la Loubère (1693, pp. 173–79) recognized only final glottal stop in Thai, and it was represented by ๑ in his early romanization of Thai. Chuenkongchoo (1956, p. 11) states that in the isolative style of speech in Standard Thai, the initial glottal plosive is different from the final glottal stop. He also states that in other styles of speech the initial glottal plosive and the final glottal stop may be absent. Here he appears to be referring to the fact that glottal stops can serve to demarcate syllable boundaries of emphatically stressed short vowels as in ๑๑raj 'what' and məʔlāʔkəw 'papaya,' which in normal conversation become araj and malakəw with stress only on the last syllable. What is interesting here is that not only did he recognize that the initial and final glottal stops were different but he also called them by different terms. The

initial one he called a plosive and the final one he called a stop. I agree with Chuenkongchoo that they normally are quite different but not in the way he described.

In modern spoken Standard Thai the word-initial glottal stop, in normal unemphatic conversation, is usually not a glottal stop at all. As stated above, the so-called word-initial prevocalic glottal stop appears to be normally simply a short form of the prephonation state of the glottis, which is usually the state of the glottis just prior to the voicing onset of an initial vowel. Prephonation is the same as the state of the glottis that is used in the Standard Thai initial voiceless unaspirated oral stops and affricates [p, t, k, tɕ]. In the prephonation state the vocal folds form a narrowed convex-convex opening medially in the glottis. The ventricular folds are abducted and the arytenoid cartilages are adducted as for modal voice with little or no air passing through the narrowed glottis until the overlap phase consisting of the release phase of the consonant's oral stricture and the onset phase of the following vowel. Prior to our having easy access to fiberoptic laryngoscopy, some of us (Kruatrachue, 1960, Henderson, 1964, and Harris, 1972, 1987) followed our kinaesthetic impressions that there was a different state of the glottis for initial Thai unaspirated stops. We correctly felt that initial unaspirated oral stops had more glottal constriction, a higher larynx, and no air passing through the glottis during the closure phase of the articulatory stricture of the stop, but we wrongly assumed that their glottal closure was complete and formed a simultaneous glottal stop. Some of us felt it was not a complete glottal closure, so we called it a simultaneous "weak or loose" glottal closure or stop, implying that the vocal folds were adducted but not completely closed. Recent access to the smaller type fiberoptic laryngoscope has brought us new information concerning the shape of the narrowed glottal opening and the fact that the arytenoid cartilages are in the position for voice and are not open as for breath. True glottal stops occur only finally in normal conversational Thai at the end of short stressed syllables, especially with nominal and verbal forms. In Thai words like **เฒ่า** [èʔ àʔ] 'to make a loud noise,' the glottal stops occur only at the end of the syllables and not at the beginning. In unstressed syllables, in unemphatic conversation, final glottal stops are dropped.

The final voiceless unreleased oral stops of Standard Thai (Abramson, 1972) are accompanied by simultaneous glottal stops. This type of overlapping oral stop and glottal stop is technically either a glottalized stop or a double articulation, depending on whose rank order of stricture one chooses to follow. If you follow Catford's (1977, pp. 188-190) rank order of strictures, then [ʔt] is a double articulation with two primary strictures of complete closure, one oral and one glottal. If you choose to follow Pike's (1943, pp. 131-53) rank order of strictures, in which all glottal articulations are secondary, then [ʔt] is a glottalized stop. The oral articulation is primary, and the glottal articulation is secondary, and the secondary meaning is made clear by the *-ized* ending of *glottalized*. All Standard Thai word-final voiceless oral stops have both oral and glottal double articulations such as [ɔʔp] 'bake,' [ɔʔt] 'starve,' and [ɔʔk] 'chest.' They are all unreleased as are Standard Thai words that end in glottal stop such as [tɔʔ] 'table' and [wɔʔ] 'defecate.' Our earlier auditory and kinaesthetic impressions were correct when we stated that the final voiceless unreleased stops in Standard Thai had both oral and glottal closures (Henderson, 1964 and Harris, 1972, 1987). The unreleased nature of Thai word-final stops was first reported by De la Loubère (1693, p. 174). Although spoken Standard Thai final voiced stops are reported in the literature (Noss, 1964, pp. 10-11), I have not recorded them in the isolative style data I have collected. I have, however, examples of

fast casual speech where final voiceless unreleased oral and glottal stops become initial voiced oral stops such as in /jîi bêt/ for /jîi sîp ?èt/ 'twenty-one.'

The closure of the vocal folds for the Standard Thai final [ʔp], [ʔt], [ʔk], and glottal stop [ʔ] includes not only the complete adduction of the true vocal folds but also the adduction, though usually not complete, of the ventricular folds. In fact I feel that it is now safe to say that when a final moderate glottal stop as in Thai [tótʔ] 'table' is formed, there is slight constriction of the whole laryngeal vestibule. The laryngeal vestibule is defined as the supraglottal cavity of the larynx that extends from the ventricular folds upwards through the aditus laryngis (Zemlin, 1988, pp. 114–115). It is formed anteriorly by the epiglottis, posteriorly by the apexes of the arytenoid cartilages, and laterally by the aryepiglottic folds. The aryepiglottic folds extend from the sides of the epiglottis to the apexes of the arytenoid cartilages. A slight retraction of the epiglottis and tongue root appears to also be a part of this slight constriction of the whole laryngeal vestibule. The partially adducted ventricular folds in the production of Thai final [ʔt] and final glottal stop [ʔ] normally cover part of the upper surface of the closed true vocal folds perhaps helping to reinforce the glottal closure. An earlier drawing of this type of reinforced glottal closure can be found in Westermann and Ward (1933, pp. 12–13). More recent discussions of the functions of the ventricular folds in the production of the glottal stop can be found in Lindqvist (1969, pp. 26–33). An argument against Lindqvist's views on glottal stop are to be found in Catford (1977, pp. 104–109). Fiberoptic photographs in Esling (1996, pp. 72–73) and Harris and Esling (in press, b.), however, clearly show the partial adduction of the ventricular folds and the slight narrowing of the laryngeal vestibule for a moderate glottal stop through its supraglottal sphincter mechanism.

It is important that we realize that phonetically initial glottal stop is not common in either modern Standard Thai or modern English. In fact, an initial glottal stop in spoken Thai is far more rare than the literature would lead one to believe. Initial glottal stop versus no initial glottal stop (zero initial) is not contrastive in either Standard Thai or English, but it is contrastive in the two Austronesian languages in Table 1. The languages are: Rennellese (Mungaba), spoken on the islands of Rennell and Bellona southeast of Guadalcanal in the Solomon Islands, and Nga'da, spoken on the island of Flores in Indonesia.

Table 1. *Contrastive Initial Glottal Stop versus No Initial Glottal Stop in two Languages.*

Rennellese		Nga'da
hanga 'pandanus'	ua 'artery'	?inu 'tiny'
anga 'road, path'	?ua 'rain'	inu 'drink'
?anga 'wake up'	au 'tattooing needle'	?ala 'God'
	?au 'gall bladder'	ala 'take'

Different kinds of glottal stops are reported in Ladefoged and Maddieson (1996, pp. 73–77). Obviously, however, one must first distinguish whether a glottal constriction is part of articulation, phonation, or initiation (airstream mechanism). For me, the glottal constriction used in the production of Thai final glottal stops in stressed syllables is both an articulation and an unphonated state of the glottis. The unphonated

state of the glottis is the voiceless type of phonation used in true glottal stops. An unphonated state of glottis accompanied by a sharp upward movement of the larynx, used in the production of ejectives, is part of initiation. More detailed fiberoptic laryngoscopic research will shed new light on the subject, but some things we already know. Some glottal constrictions are not stops at all but phonation types such as creaky voice, slightly creaky voice (stiff voice), tight throat phonation (tense voice), or ventricular voice (double voice), even though they can end in a simple glottal closure. In Standard Thai, glottal stops are used to demarcate stressed syllables with short vowels, but glottal constrictions sometimes leading to a simple glottal closure, as can occur in the cessation of voicing, are part of the prosodic features of some tones. Thai Nyo, spoken in Nakon Phanom Province in Thailand, has six tones, three of which have glottal constriction in isolative style speech. One tone is interrupted with a glottal stop midway through the syllable, similar to one of the North Vietnamese tones, and two tones end in slightly creaky voice, which may, in isolation, end in a simple glottal closure. Voiced glottal stops are by definition impossible, and in normal unemphatic Standard Thai conversation word-initial glottal stops preceding a vowel are not the norm.

CONCLUSION

In our recent fiberoptic laryngoscopy investigations (Harris & Esling, in press, a & b) John Esling and I confirmed many of Sweet's (1877, pp. 74–75), Ellis's (1869–1889, pp. 1097, 1111), and Catford's (1977, pp. 95, 114) observations on the states of the glottis used in the production of voiceless aspirated oral stops and voiceless unaspirated oral stops. We have also, for the first time, assigned the term *prephonation* to the state of glottis used in the production of voiceless unaspirated oral stops and affricates. In the production of the prephonation state of the glottis the arytenoid cartilages are adducted as for modal voice, the vocal folds form a narrowed convex-convex opening medially in the glottis and the ventricular folds are abducted as for modal voice. The airflow through the partially open glottis does not appear to be initiated until the overlapping release phase of the initial consonant and the onset phase of the following vowel. In Standard Thai the closure phase of the articulatory strictures of voiceless unaspirated stops and affricates are longer than the closure phase of voiceless aspirated stops and affricates.

Also, our observations have led me to propose here that the description of the *unphonated* state of glottis accompanying a moderate glottal stop, as in Thai [tʰɔ̌] 'table,' be expanded to include the partial adduction of the ventricular folds reinforcing the glottal closure, as well as the slight constriction of the laryngeal "tube" or vestibule. Generally speaking, there seems to be a continuum of degrees of constriction of the laryngeal vestibule beginning with the slight degree of constriction used in a moderate Standard Thai glottal stop and ending with the massive degree of constriction used in an Arabic or Nootka voiceless epiglottal or pharyngeal stop.

Finally, our observations show no evidence of an initial glottal stop occurring before an initial vowel in spoken Standard Thai. Word-initial vowels in spoken Standard Thai are, in unemphatic speech, normally not preceded by a glottal stop. It appears that a short prephonation state of the glottis immediately precedes the voicing of a word initial vowel thus forming a zero onset to the vowel. I hope our fiberoptic

laryngoscopic observations have added to our knowledge of the three voiceless states of the glottis in Standard Thai.

ACKNOWLEDGMENT

I acknowledge the collaboration of John Esling, the advice and comments of J. C. Catford concerning our prephonation state of the glottis, and the cooperation of Speech Technology Research Ltd. in making the laryngoscopic films of the vocal tract. I deeply appreciate the cooperation of Sudaporn Luksaneeyanawin and Anak Pattanavibool, both native speakers of Bangkok Thai, together with native speakers of several other languages, for making their larynxes available for fiberoptic laryngoscopic observations. Laryngoscopic observation and filming of the pharynx and larynx were made possible through Research Grant 410-93-0539 from the Social and Humanities Research Council of Canada to the University of Victoria, British Columbia.

REFERENCES

- Abercrombie, D. (1967). *Elements of general phonetics*. Edinburgh: Edinburgh University Press.
- Abramson, A. S. (1972). Word-final stops in Thai. In J. G. Harris & R. B. Noss (Eds.), *Tai phonetics and phonology* (pp. 1-7). Bangkok: Central Institute of English Language.
- Catford, J. C. (1964). Phonation types: The classification of some laryngeal components of speech production. In D. Abercrombie, D. B. Fry, P. A. D. MacCarthy, N. C. Scott, & J. L. M. Trim (Eds.), *In honour of Daniel Jones* (pp. 26-37). London: Longmans.
- Catford, J. C. (1968). The articulatory possibilities of man. In B. Malmberg (Ed.), *Manual of phonetics* (pp. 309-333), Amsterdam: North-Holland Publishing Company.
- Catford, J. C. (1977). *Fundamental problems in phonetics*. Edinburgh: Edinburgh University Press.
- Catford, J. C. (1990). Glottal consonants...another view. *Journal of the International Phonetic Association*, 9, 2-6.
- Chuenkongchoo, T. (1956). *The prosodic characteristics of certain particles in spoken Thai*. Unpublished master's thesis. University of London, London.
- Danvivathana, N. (1987). *The Thai writing system*. Forum Phoneticum 39 Hamburg: Helmut Buske Verlag
- De la Loubère, S. (1693). *A new historical relation of the kingdom of Siam* (pp. 173-190). London: Printed by F. L. for Tho. Horne.
- Ellis, A. J. (1869-1889). *On early English pronunciation* (5 parts). London: Asher & Co. and Triiber & Co.
- Esling, J. (1996). Pharyngeal consonants and the aryepiglottic sphincter. *Journal of the International Phonetic Association*, 26, 65-88.
- Gleason, Jr., H. A. (1955). *An introduction to descriptive linguistics*. New York: Henry Holt & Co.
- Harris, J. G. (1972). Phonetic notes on some Siamese consonants In J. G. Harris &

- R. B. Noss (Eds.), *Tai phonetics and phonology* (pp. 8–22). Bangkok: Central Institute of English Language.
- Harris, J. G. (1987). *Linguistic phonetic notes (1969–1979)*. Bangkok: Craftsman Press.
- Harris, J. G., & Esling, J. (in press, a). The state of the glottis during the articulatory stricture phase of voiceless unaspirated oral stops. *Journal of the International Phonetic Association*.
- Harris, J. G. & Esling, J. (in press, b). Another look at voiceless unreleased plosives. *Journal of the International Phonetic Association*.
- Heffner, R-M. S. (1950). *General phonetics*. Madison: University of Wisconsin Press.
- Henderson, E. J. A. (1964). Marginalia in Siamese phonetic studies. In D. Abercrombie, D. B. Fry, P. A. D. MacCarthy, N. C. Scott, & J. L. M. Trim, (Eds.), *In Honour of Daniel Jones* (pp. 415–424). London: Longmans.
- Holder, W. (1669). *The elements of speech*. London: Printed by T. N. for J. Martyn.
- Jones, D. (1956). *An outline of English phonetics*. New York: E. P. Dutton & Co.
- Kruatrachue, F. (1960). *Thai and English: A comparative study of phonology for pedagogical application*. Unpublished doctoral dissertation. Indiana University, Bloomington.
- Ladefoged, P., & Maddieson, I. (1996). *The sounds of the world's languages*. Oxford: Blackwell Publishing Ltd.
- Laver, J. (1994). *Principles of phonetics*. Cambridge: Cambridge University Press.
- Lindqvist, J. (1969). Laryngeal mechanisms in speech, *Quarterly Progress and Status Report*, 2–3, 26–32, Speech Transmission Laboratory, Royal Institute of Technology, Stockholm.
- Noël-Armfield, G. (1931). *General phonetics*. Cambridge: W. Heffer & Sons Ltd.
- Noss, R. B. (1964). *Thai reference grammar*. Washington, D. C.: Foreign Service Institute.
- Pike, K. L. (1943). *Phonetics*. Ann Arbor: University of Michigan.
- Sweet, H. (1877). *Handbook of phonetics including a popular exposition of the principles of spelling reform*. Oxford: Clarendon Press.
- Sweet, H. (1906). *A primer of phonetics* (3rd edition). Oxford: Clarendon Press
- Westermann, D. & Ward, I. C. (1933). *Practical phonetics for students of African languages*. Oxford: Oxford University Press
- Zemlin, W. R. (1988). *Speech and hearing science: Anatomy and physiology* (3rd ed.). Englewood Cliffs: Prentice-Hall Inc.

