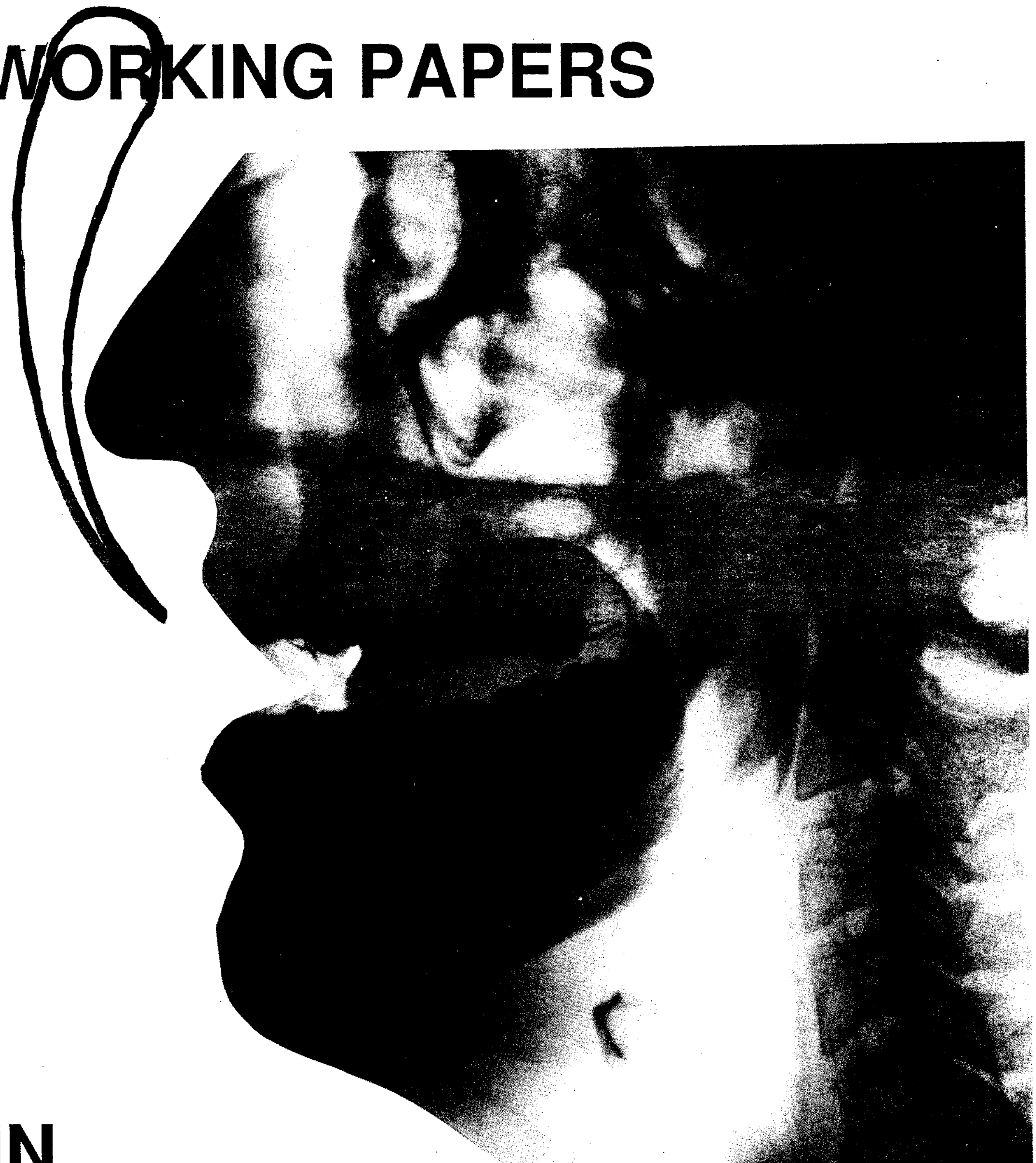
WORKING PAPERS



IN

PHONETICS

No. 66, MAY 1987

The UCLA Phonetics Laboratory Group

As on previous occasions, the material which is presented in this volume is simply a record for our own use, a report as required by the funding agencies which support the Phonetics Laboratory, and a preliminary account of research in progress for our colleagues in the field.

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A bibliography of x-ray studies of speech

Sarah N. Dart

Over the years, we at the UCLA Phonetics Laboratory have been compiling a bibliography of speech studies which contain some x-ray data. This has primarily been to gather a large data base of x-ray tracings and photographs for use in our research. During the past two years we have expanded this bibliography tremendously and entered it into the Microsoft File database program for implementation on the Apple Macintosh computer. This enables us to search entries with specific characteristics, such as language, author, or a certain segment of interest.

As a point of departure we took the existing bibliographies of A.S. Macmillan and G. Keleman (1952) and Péla Simon (1961 and 1967) and reviewed each entry that we could locate, putting it into our database format. In addition, we have searched and reviewed many more sources not listed in those previous bibliographies and are still adding to the collection. Presently our bibliography includes 282 different sources.

Format

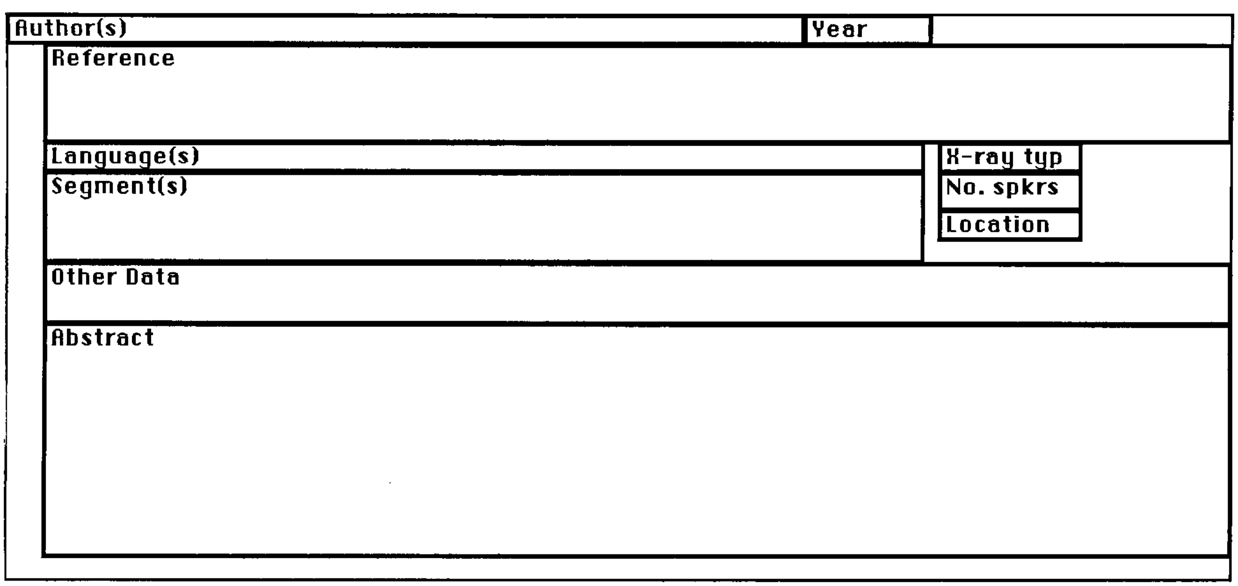

Figure 1. Blank format for each entry in the database.

We have organized each entry in our data base into ten "fields" according to the format shown above. These fields are: 1) author 2) year of publication 3) bibliographical reference 4) language involved 5) type of x-rays (i.e., still or cine-x-ray and if the latter, the frame speed) 6) segments covered (in the IPAPlus phonetic font developed at UCLA) 7) number of speakers filmed 8) location in our laboratory of the full publication 9) other data provided in addition to x-rays 10) a short abstract giving more specific information as to the type of data provided and the usefulness thereof, but not intended to be a summary of the author's claims or intent.

Applications

Each of these "fields" can be searched independently. Thus, for example, one can search for all entries from a particular language, or all those containing palatograms as well as x-rays, or those involving a particular segment. We have found this to be a useful tool in our research for easily locating articulatory data to compare segments or languages and check hypotheses. As an example, one of the laboratory members, Dr. Patricia Keating, was recently able to perform a rapid comparison of the differences between fronted velar consonants and true palatals by comparing x-rays from several different languages brought together for her by the x-ray bibliography database. Without this easy location of the relevant sources and the immediate knowledge of whether there even existed an appropriate body of data to examine this question, this study would have been tedious and time-consuming to the point of perhaps precluding the investigation altogether. With the exception of the **location** field, which refers only to our laboratory here at UCLA, this bibliography can also be useful to other phoneticians, either as a simple printout for reference or as a computer database program. The following section will clarify some questions which might arise in the use of the bibliography.

Hints for users

Most of the entries which contain photographs of x-rays, rather than tracings are very difficult to read, especially in a photocopied version.

In the "type of x-rays" field, **fps** means "frames per second". When it stands alone with no number preceding it, it means that they are cine x-rays, but we are unsure of the speed. Likewise, a question mark indicates that either the author did not state a particular detail or else we were unable to locate the information.

Most of the phonetic symbols in the IPAPlus font will be familiar to phoneticians. An exception is the following: It was found that we needed a way of distinguishing apical and laminal articulations in certain instances. In these cases the apical articulation is left unmarked and the laminal has the diacritic ◌͆ as in [s͆].

Entries which have only bibliographical information are for the most part those which we are unable to locate. Any contributions or additions will be very much appreciated. Corrections to the existing entries will also be welcomed. In the case of articles written in languages which were unfamiliar to us, we may have mistaken the meaning or missed information, in spite of our best effort.

1 Akishina, A.A. 1963

Fonetika Sovremennogo Russkogo Literaturnogo Jazyka. Moskow: Universitet Družby Narodov Imeni Patrisa Lumumby.

Russian

a,i,u,e,o,ɨ,p,pj,m,mj,f,fj,t,tj,n,nj,s,sj,ʃ,ʃj,k,kj,x,xj,l,lj,r

2 Al-Ani, S.H. 1970

Arabic Phonology: An Acoustical and Physiological Investigation. 104 pp. The Hague: Mouton.

Arabic(Jordanian, Iraqi) fps

a,a:,i,i:,u,u:,k,q,t,tʕ,ħ,ʕ

spectrograms

A description of the phonetics and phonology of contemporary, educated Arabic. 7 speakers were from Iraq and 2 from Jordan. X-ray films (speed unspecified) were taken of isolated vowels and plain vs. pharyngealized consonants in CV sequences and also in real word minimal pairs. Tracings are given of the consonants in various vowel environments and the vowels following different consonants, as well as in isolation. Numerous spectrograms are included.

3 Ali, L.H., and R.G. Daniloff 1972

A cinefluorographic-phonologic investigation of emphatic sound assimilation in Arabic. In A. Rigault and R. Charbonneau (eds.), Proc. of the 7th Intern. Congress of Phonetic Sciences (Montreal, 1971). The Hague: Mouton. 639-648. (Expanded version also in Studia Linguistics 26 (2): 81-105.)

Arabic(Iraqi) 100 fps

i,ɪ,ʊ,u,a,æ,b,s,t,k,bʕ,sʕ,tʕ,kʕ 3

X

Three native speakers of Iraqi Arabic (Baghdad dialect) were filmed at 100 frames/sec, uttering both nonsense and real word minimal pairs containing [b,s,t,k] and their emphatic counterparts. The consonants were uttered in the environment of the vowels [i,u,a] and their lax counterparts [I,U,ae]. Measurements were made particularly of pharynx width which was found to be less during emphatic consonants and surrounding segments. Results are discussed in terms of Jakobson's feature "flat" and Chomsky and Halle's analysis of emphatics in Sound Pattern of English. No actual tracings are given.

4 Alonso, D., A. Zamora Vicente, M.J. Canellada de Zamora 1950

Vocales andaluzas. Nueva Revista de Filología Hispánica 4:3, 209-230.

Spanish(Andalusian)

a,e,ɑ,o,s

still

plural

X

kymograms, palatograms

X-rays, kymograms and palatograms were taken of subjects speaking Andalusian Spanish. Shown are 10 x-rays of vowels and /s/. Both retracted and non-retracted /a/ and /e/ tongue shapes are clearly visible. The bulk of the paper is devoted to Andalusian phonology.

5 Amerman, J.D., R. Daniloff, and K. Moll 1970

Lip and jaw coarticulation for the phoneme /æ/. J. Speech and Hear. Rs. 13.1: 147-161.

English(Am.)

æ

150 fps

4

X

Four male speakers of Midwestern American English were filmed at 150 frames/sec. uttering phonetic sequences containing the vowel [ae] embedded in meaningful sentences. Incisal opening and lip retraction were measured to judge coarticulation effects on adjacent segments. No actual tracings are included.

6 Balasubramanian, T. 1972

The Phonetics of Colloquial Tamil. Ph.D. Dissertation, University of Edinburgh.

Tamil

a,aː,ɪ,iː,ʊ,uː,eː,oː,ɨː,ə,ʈ ,k,ɻ

still

1

L

palatograms,airflow tracings, spectrograms, labiograms, etc.

An exhaustive study of the phonetics of colloquial Tamil using not only x-rays, but palatograms, airflow tracings, spectrograms, labiograms, etc., etc. Only 13 x-rays are included: 10 tracings of vowels and 3 photographs of x-rays showing k and retroflex t and r.

7	Bao, H. and L. Yang 1986 The Articulatory Movements of Standard Chinese. Beijing: Beijing Language Institute Press. Mandarin fps a, i, e, ɛ, o, u, y, tʂʅ, tsɿ, əɹ, ai, ei, au, ia, iɛ, ua, uə, yɛ, iau, iəu, uai, uei, n, ŋ, b, p, m, f, 2 d, t, l, g, k, h, tɕ, tɕʰ, ɕ, tʂʰ, ʂ, ʐ, tsʰ, s X An x-ray videotape available from the Beijing Language Institute. Both sagittal cine-x-rays and frontal cine-photographs of the lips are given simultaneously. 258 utterances are shown to illustrate most of the sounds of Mandarin, including "retroflexed" syllables and tone contrasts. Prospective users should note that this is a 1/2" per frame tape which uses PAL color standards.
8	Barth, E. and E. Grunmach 1907 Röntgenographische Beiträge Zur Stimmphysiologie. Archiv fuer Laryngologie und Rhinologie. 19: 396-407. German still i, e, o, u, a, y, ø, ɛ, oa ? X A very early study with still x-rays.
9	Benson, D. 1972 Roentgenographic cephalometric study of palatopharyngeal closure of normal adults during vowel phonation. Cleft Palate Journ. 9.9: 43-50. English(Am.) ? a, i, u 30 Study by cephalometric roentgenography of 15 male and 15 female speakers of American English uttering [a], [i] and [u] in sustained phonation. He observed that for many speakers the velopharyngeal closure was not complete, particularly when uttering the vowel [a]. He also measured the height of closure or area of greatest constriction which again varied between [a] and the other two vowels. No actual tracings are given.

10 Bernard, J.R. L-B 1970

A cine-x-ray study of some sounds of Australian English. Phonetica 21: 138-150.

English(Austral.) 24 fps

i,ɪ,ɛ,æ,a,ɒ,ɔ,ʊ,u,ɜ,ʌ,ə,aʊ,aɪ,ɔɪ,ɪə,ɛə,ʊə,d 12

X

spectrograms, F charts

X-ray films were taken at 24 frames/sec. of 12 male speakers of Australian English representing three social class dialects. Each subject read a word list of approx. 30 words illustrating vowels in the frame /h_d/ and /u/, /a/ and /ae/ in a nasal frame. Lip height, tongue height and height of the velum are discussed. Only three tracings are given, one of [u] for one speaker over time, one of [u] and [E] target values for one speaker and the last, for the same speaker, [d] occlusions after [i] and [A]. Spectrograms were also made and vowel charts plotted from F1 and F2 values. F3 frequency was found to correlate with lip aperture.

11 Bgažba, X.S. 1964

Bzybskij Dialekt Abxazskogo Jazka. Tbilisi

12 Björk, L. 1961

Velopharyngeal function in connected speech, studies using tomography and cineradiography synchronized with speech spectrography. Acta Radiologica Suppl. 202.

fps & tomo

spectrograms

Contains technical details of x-ray method and dosages.

13 Bladon, R.A.W. and F.J. Nolan 1977

A videofluorographic investigation of tip and blade alveolars in English. Journal of Phonetics 5: 185-193.

English(Br.) fps

s,z,t,d,n,l 8

X

English alveolar consonant articulation was examined to identify apical vs. laminal tongue constrictions. Coarticulation effects between apical and laminal articulations are also discussed. Idealized tracings are given of 5 different tongue shapes for classificatory purposes. The data is represented in graphs of tip height vs. blade height.

14 Boff, M.-C. 1983

Contribution a l'étude expérimentale des consonnes d'arrière de l'arabe classique. Travaux de l'Institut Phonétique de Strasbourg No.15.

Arabic(Moroccan) still

χ,ʁ,ħ,ʕ,h,ʔ,k,q 1

L

spectrograms, oscillograms

A Ph.D. dissertation on the back consonants of Classical Arabic (Moroccan), i.e. [X,R,H,?,h,?] with some mention also of [k] and [q]. 4 male speakers were recorded for spectrograms and oscillogram tracings (audio-larynx, nose, mouth and oral air flow) but only one of them was used for the x-ray films. 58 tracings are given, many representing more than one token. A detailed description of each sound is given in articulatory and acoustic terms.

15 Bolla, K. 1980

A phonetic conspectus of Hungarian. The articulatory and acoustic features of Hungarian speech-sounds. Magyar Fonetikai Fuzetek (Hungarian Papers in Phonetics) Vol.6

Hungarian fps

aː,ɔ,o,oː,u,uː,y,yː,i,iː,ø,øː,eː,e,ɛ,ə,b,p,m,ɱ,d,t,n,ɟ,c,ɲ,g,k,ŋ,v,f,z,s,ʒ,ʃ,j, 1

ç,x,x̟,ɦ,h,dz,ts,dʒ,tʃ,r,l,bv,pf L

labiograms, palatograms, spectra, spectrograms, glottograph &waveforms

An x-ray photograph and corresponding tracing of the oral cavity are given for each speech sound in Hungarian (of one male speaker). X-ray photographs of the pharynx and five very small x-ray photographs taken from five points in time for each sound are also shown. Along with this are provided labiograms, palatograms, spectra, spectrograms and glottograph and waveform records. Additional labiograms are provided from a female speaker.

16	Bolla, K. 1981a A magyar hosszú mássalhangzók képzése (Kinoröntgenografikus vizsgálat számítogéppel) (The articulation of Hungarian long consonants (Cineradiographic analysis with computer)). Magyar Fonetikai Füzetek (Hungarian Papers in Phonetics) No.7: 7-55. Hungarian — fps b:,p:,d:,t:,m:,n:,ɟ,c:,g:,k:,ɲ:,r:,v:,f:,z:,s:,ʒ:,ʃ:,j:,l:,x:,ɦ:,dz:,ts:,dʒ:,tʃ — 1 : — L,X X-ray films synchronized with video-recordings were taken of a single speaker uttering minimal pairs in Hungarian, illustrating short vs. long consonants. The data shown are exclusively of the long consonants. Two different systems are used for recording measurements: a 22 point system (of which 7 are along the tongue) and a 32 point system (13 along the tongue). Numbers corresponding to the placement of each of these points were fed into a computer and the schematic drawings given are the result. There are only 6 examples given from the 32 point system. The bulk of the data is from the 22 point system with 5 drawings corresponding to 5 points in time for each of 26 lona consonants. Closure timina in milliseconds is also aiven as well as the raw number data
17	Bolla, K. 1981b A magyar magánhangzók és rövid mássalhangzók képzési saját-ságainak dinamikus kinoröntgenográfiai elemzése (The articulation of Hungarian vowels and short consonants. A cineradiographic analysis). Magyar Fonetikai Füzetek (Hungarian Papers in Phonetics) No.8: 5-62. Hungarian — fps a:,ɔ,o,o:,u,u:,y,y:,i,i:,e̞:,e,ɛ̞,ɛ,ø,ø:,b,p,m,ɱ,d,t,n,ŋ,ɟ,c,ɲ,r,g,k,v,f,z,s,ʒ,ʃ,j — ? ç,x,x̞,x,h,bv,pf,dz,ts,dʒ,tʃ,l — L,X The complement to his study on long consonants (Bolla 1981a). The method is the same as described for that study using the 22 point system. Schematic drawings of the vocal tract are given of 16 vowels (most of which are members of long and short pairs) and 33 consonants. Each segment is represented by 5 figures from 5 points in time during the articulation of that segment.
18	Bolla, K. 1981c Az Amerikai Angol beszédhangok atlasza: A beszédhangok artikulációs és akusztikus sajá tságai(A phonetic conspectus of American English: The articulatory and acoustic features of American English speech-sounds). Magyar Fonetikai Füzetek (Hungarian Papers in Phonetics) Vol.9. English(Am.) — fps a,ɒ,ʌ,ɔ,ɷ,u,i,ɩ,ɛ,æ,ɚ,ə,aɩ,aɷ,ɔɩ,oɷ,eɩ,b,p,m,d,t,n,g,k,ŋ,ɹ,w,v,f,ɱ,ð,θ,z,s,ʒ, — 1 ʃ,j,ç,h,ɫ,l,dɹ,tɹ,dz,ts,dʒ,tʃ — L frontal &sagittal cine-labiograms, palatograms, linguagrams, spectrograms,spectra,glottograms and waveforms A similar format to his 1980 study of Hungarian, except instead of showing x-ray photographs, the kind of computer-produced schematic drawings described in Bolla (1981a) are given. Data illustrate all American English speech sounds in several different environments.

No.	Entry
19	Bolla, K. 1981d A Conspectus of Russian Speech Sounds. (translated from the Hungarian edition, Magyar Fonetikai Füzetek, Hungarian Papers in Phonetics, Vol.11, 1982) Cologne & Vienna: Böhlan. Russian — fps i̯,e,ɛ,a,o,u,ɨ,ə,b,bj,p,pj,m,mj,d,dj,t,tj,n,nj,g,gj,k,kj,v,vj,f,fj,z,zj,s,sj,ʒ,ʃ, — 1 ʒj:,ʃj:,j,ç,ɣ,x,xj,dz,ts,dʒ,tʃj,r,rj,ɫ,lj — L photos, contour spectrogram, spectrographic section, oscillograms w/filt. Contains data on 78 phonemes and/or allophones of Russian, mostly spoken by the same male speaker. Original x-ray photos and tracings, accompanied by labial photographs, a contour spectrogram, a spectrographic section (spectrum), and oscillograms filtered under four different conditions. Palatograms and linguagrams are also included, but these are of two different female speakers.
20	Bolla, K. 1985 A phonetic conspectus of Finnish. Magyar Fonetikai Füzetek (Hungarian Papers in Phonetics), Vol.14. Finnish — 50 fps a,a:,o,o:,u,u:,i,i:,y,y:,e,e:,ø,ø:,ɛ,ɛ:,au,ou,uo,eu,ue,ai,ia,oi,ui,iu,yi,ei,ie,ɛi — 2 iɛ,øi,øy,yø,ɛy,eɛ,ɛe,p,p:,m,,m:,d,t,t:,n,n:,k,k:,ŋ,ŋ,r,r:,v,s,s:,j,ɦ,ç,l,l: — L Frontal & sagittal cine-labiograms, palatograms, linguagrams, spectrograms, spectra, glottograms, waveforms. A similar format to his studies of American English (Bolla (1981c) and Russian (Bolla 1981d) with data from two different speakers of Finnish.
21	Bolla, K. and E. Földi 1981 A lengyel beszédhangok képzési és akusztikus sajátságairól' (Articulatory and acoustic features of Polish speech sounds). Magyar Fonetikai Füzetek (Hungarian Papers in Phonetics), Vol.7: 91-140. Polish — still a,o,u,e,ɨ,i,ã,õ,ũ,ẽ,ɾ̃,ɾ̃,b,p,m,bj,pj,mj,d,t,n,dj,tj,nj,g,k,ŋ,gj,kj,ŋj,r,rj,w,l,lj, — 1 v,f,z,vj,fj,zj,j,x,ç,dz,ts,tsj,dʒ,tʃ,tʃj,dʒj — L spectrograms, spectra, glottographic tracings, waveforms, palatograms, linguagrams, formant frequencies A study of speech sounds in Polish including x-ray tracings, spectrograms, spectra, glottographic tracings and waveforms for each segment examined. The following article in the same journal gives palatograms and linguagrams for the same speaker and the same segments. The text gives a short description (in Hungarian) of each segment. In the next number of the journal frontal and sagittal moving pictures of the lips of the same speaker are given at several points in time for each segment.

22 Bolla, K. and L. Valaczkai 1986

A Phonetic Conspectus of German. Magyar Fonetikai Füzetek (Hungarian Papers in Phonetics) 16.

German — 50 fps

a,aː,ɔ,o,oː,ɷ,ʊ,uː,y,yː,ɩ,i,iː,e,eː,ɛ,ɛː,ə,œ,ø,øː,au,ai,ɔi,p,b,m,t,ṭ,d,ḍ,n,nj,k, — 1

g,ŋ,ʁ,f,v,s,z,ʃ,ʒ,j,ç,x,h,pf,ts,tʃ,l — L

formant frequencies, relative intensity, labiograms, palatograms, linguagrams,spectrograms,spectra,waveforms,glottograms,artic.measrmts. measurements

A similar format to Bolla 1985 with a thorough documentation of the German speech sounds of one male speaker.

23 Bonnot, J.-F. 1977

Recherche expérimentale sur la nature des consonnes emphatiques de l'Arabe classique. Travaux de l'Institut de Phonétique de Strasbourg, No.9: 47-88.

Arabic(Saudi) — 40 fps

t,tˤ,k,q,a,aː — 1

X

oscillomink traces, spectrograms w/ intensity tracings.

X-ray films at a speed of 40-42 frames/sec were taken of one male speaker of Classical Arabic (Saudi). The study compares emphatic and non-emphatic /t/ and shows how this distinction is different from the distinction between the velar consonant /k/ and the uvular /q/. All consonants were observed, simple and geminate, in the environment of the vowels /a/ and /a:/ in initial, intervocalic and final positions. In addition to the x-ray data, oscillomink traces were taken of audio-larynx, audio nose, audio-mouth and oral air flow and spectrograms were made with intensity tracings., The author proposes a definition of emphasis in Arabic consonants in terms of muscular force employed in articulation. 8 tracings are given, 4 each comparing 2 different segments and 4 comparing one

24 Bonnot, J.-F. 1979

Etude expérimentale de certains aspects de la gémination et de l'emphase en Arabe. Travaux de l'Institut de Phonétique de Strasbourg, No.11:109-118.

Arabic — 42 fps

t,tˤ,a — 1

L,X

spectrograms

A study of the position of the tongue during Arabic simple and geminate emphatic and plain /t/ and during the adjacent vowel /a/. Formants were measured from spectrograms and changes in their values are compared to changes in tongue position. No actual tracings are given; only graphs of measurements taken from the x-rays.

25 Bothorel, A. 1969-70

Contribution a l'étude descriptive des latérales de l'Albanais. Travaux de l'Institut de Phonétique de Strasbourg, No.2: 133-144.

Albanian 50 fps

l̪,l̠ 1

L

spectrograms, palatograms

A study of the two lateral phonemes in Albanian (apical dental and apical alveolar). 4 tracings are given, two of each type of lateral, which enables one to clearly see the tongue backing in the dental lateral. Spectrograms are also provided for the same speaker, as well as palatograms from two other speakers whose pronunciation differed from the speaker x-rayed.

26 Bothorel, A. 1971

A propos du Breton parlé a Argol: quelques observations sur les consonnes géminées. Travaux de l'Institut de Phonétique de Strasbourg, No.3: 195-233.

Breton 48fps

l,ll,o,n,nn,e 1

L

spectrograms, intensity tracings, articulatory measures

The author examines the difference between single and so-called 'geminate' sonorants in Breton (Argol dialect) as well as differences between the preceding vowels (where most of the difference seems to lie). X-ray films were taken at 48 frames/sec with synchronized sound recordings of one subject and additional acoustic recordings were made of two other subjects. Composite tracings are given of /l/ vs. /ll/, /o(l)/ vs. /o(ll)/, /n/ vs. /nn/ and /e(n)/ vs. /e(nn)/. Spectrograms with intensity tracings and graphs of some articulatory measures over time are also provided.

27 Bothorel, A. 1975

Positions et mouvements de l'os hyoïde dans la chaîne parlée. Travaux de l'Institut de Phonétique de Strasbourg, No.7: 80-132.

Breton 48 fps

1

X

spectrograms, graphs of hyoid bone position

One speaker of Breton was filmed at 48 frames/sec saying 147 meaningful sentences. The position of the hyoid bone was noted and measured, and the values for specific segments tabulated. Many findings are discussed, including, for example, a backward movement of the hyoid bone for back vowels and velars and a forward movement for palatals and front vowels. The figures are in the form of graphs of the position of the hyoid bone. Several spectrograms from a simultaneous recording are also included.

28 Bothorel, A. 1978

Déplacement vertical de l'os hyoïde et variation de la fréquence fondamentale. Travaux de l'Institut de Phonétique de Strasbourg, No.10: 120-132.

Breton

48 fps
2
X

Using the data from his 1975 study as well as new x-ray data from a different speaker who pronounced sustained vowels at different pitches, the author concludes that although in singing and sustained vowel phonation there is a positive correlation between the height of the hyoid bone and pitch, in normal speech the correlation is negative. No x-rays are shown.

29 Bothorel, A. 1979

La cavité pharyngale: configuration et variations dans la chaîne parlée. In Mélanges a la memoire de Louis Michel. Montpellier. 105-118.

30 Bothorel, A. 1982

Etude Phonétique et Phonologique du Breton Parlé a Argol (Finistère-sud). Lille Atelier National reproduction des thèses, Université Lille III.

Breton
p,b,m,f,v,t,d,n,s,z,tj,dj,ɲ,ʃ,ʒ,k,g,ŋ,x,ʁ,l,ʎ,j,w,h,i,e,ɛ,ə,a,u,o̩,o,ɔ,y,ø,œ,aɛ,
au,ao,ɛi,ɛo,ẽ,ɛ̃,ɔ̃,ɑ̃,œ̃,ɑ̃ɔ̃,ɛ̃ɔ̃

still
?
L

spectrograms, palatograms,graphs of hyoid bone movement

An exhaustive study of a dialect of Breton, including 124 x-ray tracings comparing different segments or the same segment in different contexts. Spectrograms and palatograms are given of a few selected segments.

31 Bothorel, A., G. Brock & G. Maillard-Salin 1980

Contribution a l'étude des rapports entre les mouvements de l'os hyoïde et le déplacement du larynx. Travaux de l'Institut de Phonétique de Strasbourg, No.12: 225-269.

Finnish, French — 50 fps,still
i,y,u,a,e,o — 6
L,X

The authors made still x-rays of two subjects--one French, one Finnish-- repeating isolated vowels ([i,y,u,a,e,o]) at different frequencies and different amplitudes and cine x-rays at 50 frames/sec of 4 French subjects uttering meaningful sentences containing the vowels in question. The relative positions of the hyoid bone and the larynx were then measured and the variations due to frequency, stress and vowel quality noted. 6 x-ray tracings showing the positions of the tongue, hyoid bone and larynx are given of two subjects' production of [i,y,u].

32 Brichler-Labaeye, C. 1970

Les voyelles françaises: mouvements et positions articulatoires à la lumière de la radiocinématographie. Bibl. fr. et romane A, 18. Paris: Klincksieck.

French — 50 fps
i,y,e,ø,ɛ,œ,a,ɑ,o,ɔ,u,ə,ɛ̃,ø̃,õ,ɑ̃ — 1
X

A thorough documentation of all French vowels, with 400 tracings, some following vowels over time and others comparing two different vowels. Most are from a single speaker. The tracings are of only the anterior two-thirds of the vocal tract.

33 Brock, G. 1977

Méthode de synchronisation graphique image-son pour l'exploitation des films radiologiques. Travaux de l'Institut de Phonétique de Strasbourg, No.9: 221-232.

fps
0
X

A description of the x-ray cinematography and sound synchronization system used for all the experiments which come out of the University of Strasbourg.

34 Brunot, F. and C. Bruneau 1933

Précis de Grammaire Historique de la Langue Française. Paris: Masson. (Note: The tracings have been deleted from later editions.)

French
α,ᾶ,a,i̦,u̦,p,ț,k̦,ʁ,r

still
1
X*

Included in this book on the history of French grammar are a number of tracings from the same study as Chlumsky 1938. Since the consonants were not reproduced in that work, this book provides additional data. /k/ and t are shown in plain and palatalizing environments.

35 Bryzgunova, E.A. 1963

Praktičeskaja Fonetika i Inťonacija Russkogo Jazyka. Moscow: Izdatel'stvo Moskovskogo Universiteta.

Russian, French
a,e,o,u̦,i̦,j,n̦,nj,f,fj,m̦,mj,p,pj,l̦,lj,t,tj,ts,tʃ,s,sj,ʃ,ʃj,k̦,kj,x̦,xj,ç

fundamental frequency contours

A study of the phonetics of Russian which includes x-ray tracings and work on intonation. Vowels are shown in different contexts. Also included are two tracings of French.

36 Bukshaisha, F.A.M. 1985

An Experimental Phonetic Study of Some Aspects of Qatari Arabic. Ph.D. thesis, University of Edinburgh.

Arabic(Qatari)
ħ,ʕ,ʕʕ,s,s

fps
2
X*

We have photographs of some of the x-rays included in this thesis. The segments indicated are shown in several different environments by two speakers.

37 Bulanin, L.L. 1970

Fonetika Sovremennogo Russkogo Jazyka. Moscow: Izdatel'stvo «Vysšaja Škola».

Russian

a,e,i,ɨ,u,o,j,b,m,mj,f,fj,d,dj,n,nj,s,sj,l,lj,r,rj,k,kj,x,xj

X*

formant chart, palatograms

A book on Russian phonetics which takes its vowel tracings and some of its consonant tracings from Matusevič and Ljubimova 1963 and the remaining consonant tracings from Skalozub 1963,1966.

38 Butt, A.H. 1973

Articulation with Reduced Oral Sensory Control: A Cineradiographic Study. Ph.D. dissertation. Purdue University.

39 Carmody, F.J. 1936

Radiographs of thirteen German vowels. Archives Neerlandaises de Phonetique Experimentale, V.12: 27-33.

German

i,ɪ,e,ɛ,y,ʏ,ø,œ,ɑ,ɔ,o,ʊ,u

still

?

X

Twelve very small tracings of single German vowels are given as well as 3 large tracings, each showing 4 or 5 vowels simultaneously.

40 Carmody, F.J. 1941

An x-ray study of pharyngeal articulation. University of California Publications in Modern Philology, 21.5: 377-384.

English, French, German, Polish, Portuguese, Russian, Spanish — still / plural / O,X

pharynx measurement charts

The only tracing given here depicts the highest point of the tongue for 24 vowels, but which languages which vowels come from is not specified. Charts of breadth of pharynx for vowels and consonants are given for French, German, Texas American, Oxford English and Mexican Spanish speakers. Charts of length of pharynx are given for vowels and consonants of French (2 speakers), German, New England American, Oxford English, Polish, Russian, Portuguese and Mexican Spanish.

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41 Carney, P.J. and K.L. Moll 1971

A cinefluorographic investigation of fricative consonant-vowel coarticulation. Phonetica 23: 193-202.

English(Am.) — 100 fps / 2 / X

i,a,u,s,z,f,v

Investigates vowel to fricative and vowel to vowel coarticulation in two speakers of American English (Mid-West). X-ray films were taken at 100 frames/sec of all possible combinations of hVCV where V=i,a,u and C=s,z,f,v. Each segment was also said in isolation. Composite tracings are given of: /u,a,i/ in isolation; /f,v,s,z/ each in the environment of u_u, a_a, and i_i as well as in isolation; /u,f,i/ in /hufi/; /a,v,i/ in /havi/; /u,s,i/ in /husi/; /i,z,a/ in /hiza/ and /i/ in /hiva/, /hivu/ and /hivi/.

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42 Catford, J.C. 1983

Pharyngeal and laryngeal sounds in Caucasian Languages. In D.M. Bless and J.H. Abbs (eds.), Vocal Fold Physiology: Contemporary Research and Clinical Issues, pp. 344-350. San Diego: College-Hill.

Abkhaz (Bzyb), Dargi, Tsakhur, Udi — still / ? / X

χʕ,χʷʕ,ʜ,ʢ,oʕ,aʕ

formant frequencies

Contains tracings of Abkhaz (Bzyb dialect from Bgažba 1964) pharyngealized uvular fricatives, Dargi deep pharyngeal or epiglottal fricatives (from Gaprindasvili 1966), and Tsakhur and Udi pharyngealized vowels. Formant frequencies are also given for the vowels.

43 Charbonneau, R. 1970

Le phonème /ɛ̃ / en français canadien. In B. Hala, M. Romportl and P. Janota (eds.), Proceedings of the Sixth International Congress of Phonetic Sciences (Prague 1967), pp. 253-264. Prague: Academia.

French(Cdn.) 36 fps

ɛ̃,p,k,f,s,p,t 2

X

spectrograms

Describes in detail the realization of [ɛ̃] in French-Canadian Two speakers were filmed at 36 frames/sec saying phrases consisting of 4 syllables, the last one containing [ɛ̃]. 33 composite tracings are given, showing successive frames of the syllables. Spectrograms are also given of the same phrases and of the corresponding oral vowels.

44 Charbonneau, R. 1971

Etude sur les voyelles nasales du français canadien. Paris: Klincksieck.

French(Cdn.) 36 fps

ɛ̃,ɛ̃:,ɛ,ɛ:,ɑ̃,ɑ̃:,a,a:,ɑ,ɑ:,ɔ̃,ɔ̃:,ɔ:,o,o:,œ̃,œ̃:,ø,p,b,m̪,t̪,n̪,ɲ,k,g,f,s,ʒ,l̪,r 2

L

spectrograms, articulatory measures

A study of nasal vowels (and their oral counterparts) in the speech of two working class speakers of Canadian French. Real word sentences were used. Tracings are given of 5 or 6 consecutive frames showing the entire syllable for each vowel studied, so a number of consonants are thus also included in the data. Spectrograms of the syllables discussed and tables of articulatory measures are also given.

45 Charbonneau, R. and A. Marchal 1979

Considérations sur la définition acoustique et perceptuelle des "R" en français québecois. In G. Rondeau, G. Bibeau, G. Gagné and G. Taggart (eds.), Vingt-cinq Ans de Linguistique au Canada: Hommage à Jean-Paul Vinay par ses Anciens Élèves, pp. 291-303. Montréal: Centre Educatif et

French(Cdn.) 36 fps

r,ʀ,ʁ 5

X

spectrograms

An attempt to show the existence (or lack thereof) of postvocalic /R/ in final position of an accented syllable in Canadian French. Speakers with each of the three /R/ variants from two social classes were recorded and spectrograms made of /R/ in final as well as intervocalic position for comparison. It was found that even when /R/ was not audible or visible on the spectrogram, clues to its existence were found in the length, transitions, or fundamental frequency of the preceding vowel. 3 x-rays are given of [r] in final position for one speaker.

46 Charbonneau, R. and B. Jacques 1972

[ts] et [dz] en français canadien. In A. Valdman (ed.), Papers in Linguistics and Phonetics to the Memory of Pierre Delattre, pp. 77-90. The Hague: Mouton.

French(Cdn.)
t,ts,d,dz,i,ɪ,y,e,ẽ,ɑ̃,e,ɑ,ɔ̃,u

36 fps
1
X

18 x-ray tracings illustrate the palatalization and affrication of t and d before high front vowels in Canadian French. Most of the tracings (from a film at 36 frames/sec) depict several successive moments in time before, during and after the segments in question. Given are: rest position, [t,u] of 'tout'; [Õ,d,e] of 'bondés'; rest, [ts,y] of 'tu'; [e,ts,i] of 'plaintif'; [ã,ts,y] of 'tentures'; [E,ts,i] of 'petit' and [a,dz,y] of 'a du'.

47 Chiba, T., and M. Kajiyama 1958

The Vowel: Its Nature and Structure. Tokyo: Tokyo-Kaiseikan Pub. Co. Second edition published by Phonetic Society of Japan.

English, German, Japanese
i,ɪ,e,ɛ,a,ɑ,æ,ɔ,o,u,ʊ,y,ø

still

X*

Although this book is not primarily concerned with x-ray data, some x-rays are included. Given are tracings showing the area from the lower lip to below the larynx for Japanese [i] uttered in 4 different voice qualities: "soft voice," "ordinary voice," "sharp voice" and falsetto, and for English [u,i,O,e,a,æ]. X-ray tracings showing the area from the nose to below the hyoid bone are given for the German vowels: /u,U,ü,o,O,ö,a,ä,i,I,e,'/.

48 Chlumsky, J. 1938

Radiographies des voyelles et des semivoyelles françaises. Prague. Also published as J. Chlumsky, A. Pauphilet and B. Polland (1938), Radiografie Francouzskych Samohlásek a Polosamohlásek. Prague: Czech Academy.

English, French
i,e,ɛ,a,ɑ,o,ɔ,u,y,ø,œ,ɛ̃,ɑ̃,õ,œ̃,j,w,ɥ,ʊ

still
2
X*,Stanford

A pioneering work with x-ray photographs and tracings of the French vowels and glides of two speakers of Parisian French. Included is also one x-ray of English lax [u].

49 Croatto, L. 1966

Les malformations congénitales du tractus vocal. In A. Moles and B. Vallancien (eds.), Phonétique et Phonation. Paris: Masson et Cie. 91-112.

Italian 24 fps

p,a,n,e plural

X

Studies Italian subjects with various malformations in the larynx and pharyngeal cavity in general. 40 successive frames are shown of the vowel [a] and 70 successive frames of the word [pane]. Unfortunately, the images are so small that it is nearly impossible to make use of them.

50 Curry, R. 1938

The physiology of the contralto voice. Archives Néerlandaises de Phonétique Expérimentale 14: 73-79.

still

a,i,u 1

X

table of measurements

A trained singer (female, contralto) sang [a,i,u] each at three different pitches. 8 of the resulting x-rays are given (u at a medium pitch is not included). A table is included of various measurements: jaw opening, lip aperture, pharynx width, displacement of hyoid bone, etc.

51 Daneš, F., B.Hála, A. Jedlička, and M. Romportl 1954

O Mluveném Slové. Praha.

Czech ?

a,e,i,o,u,p,b,m,t,d,n,c,ɟ,ɲ,k,g,ŋ,f,v,h,s,z,ʃ,ʒ,j,x,ts,tʃ,l,r,ř ?

X*

palatograms, labiograms

Includes x-ray tracings, palatograms and labiograms of most Czech sounds.

52 Daniloff, R. and K. Moll 1968

Coarticulation of lip rounding. Journal of Speech and Hearing Research, 11.4: 707-721.

English 150 fps

n,s,t,r,u 3

X

A study using high speed cineradiography, involving the syllables [bu], [stu], [stru], and [nstru] spoken by three English speaking subjects. The most interesting result is that the lip rounding for [u] begins as early as possible in the sequence of preceding consonants, although since /r/ is rounded for many speakers, the results are not as convincing as otherwise. No actual tracings are shown, only graphs of lip protrusion over time.

53 DeClerk, J.L., L.S. Landa, D.L. Phyje, and S.I. Silverman 1965

Cinefluorography of the vocal tract. In D.E. Cummins (ed.), Proceedings of the 5th International Congress on Acoustics.

54 Delattre, P. 1966

Voyelles diphtonguées et voyelles pures. In P. Delattre, Studies in French and Comparative Phonetics, pp.95-104. The Hague: Mouton.

English(Am.), French 24 fps

ŋ,oʊ,f,eɪ,d,uʷ,b,ij,o,v,e,u,i 12

X

frontal and profile cine-photographs of lower face

A comparison between the diphthongized vowels of American English and the corresponding 'pure' vowels of French. X-ray films (24 frames/sec) of 6 subjects from each language speaking real-word sentences were chosen for analysis. Tracings of successive frames are shown for one speaker and 4 syllables in each language. Also given are frames from cinephotographs taken simultaneously showing both frontal and profile views of the lower half of the face. The images on the page are quite small, but show the movements discussed clearly enough. Discussion focuses on the constantly changing vowel quality of the Americans and the relatively stable vowel quality of the French speakers.

55	Delattre, P. 1968 Divergences entre la nasalité vocalique et consonantique en français. Word 24: 64-72. French 24 fps ɛ̃,œ̃,ɔ̃,ɑ̃,ɲ,n,m,ŋ 1 X spectrograms In a discussion on the articulatory and acoustic differences between nasal consonants and nasal vowels, 12 small x-ray tracings are given. Four of them are supposed to represent vowels in Old French, and therefore are not real examples of any language. The others are from modern French. Spectrograms of oral and nasal vowels and nasal consonants are also given.
56	Delattre, P. 1971 Pharyngeal features in the consonants of Arabic, German, Spanish, French, and American English. Phonetica 23: 129-155. Arabic, English(Am.), French, German, Spanish 24 fps ʕ,ħ,ʕ,χ,q,a,i,u,z,ʃ,x,ʀ,t,m,ŋ,i,ɩ,ɛ,a,u,ɷ,ə,d,e,ʁ,o,y,ɹ,l,b,k 5 X Includes a total of 157 tracings of approximately 2 x 2 cm from a motion film of the speed 24 frames/sec. Although small, the tracings are clear and can be useful. Except for the French examples, all the tokens are taken from real words. Surrounding segments are also shown so coarticulation effects can also be noted. Tracings are included from Lebanese Arabic, Northern German, Madrid Spanish, French and American English. Formant values are discussed although no figures (e.g. spectrograms) are given.
57	Delattre, P., and D. Freeman 1968 A dialect study of American R's by x-ray motion picture. Linguistics 44: 29-68. English(Am.), (Br.) 24 fps ɹ,ɹ̣ 19 X* spectrograms? Defines 8 types of /r/ (2 British and 6 American), giving articulatory descriptions as well as acoustic correlates from spectrograms. Only 8 tracings are given, one illustrating each type of /r/.

58 Delgado Martins, M.R. 1978

Caderno de Fonética do Português. Lisbon: Laboratório Fonética Fac. de Letras de Lisboa.

Portuguese(Lisbon) 50 fps

a,ɐ,ɛ,e,ɔ,o,i,u,ə,ẽ,ɐ̃,õ,ĩ,ũ,p,t,k,f,s,ʃ,m,n,ɲ,l,ʎ,r, 1

X

spectrograms, amplitude records, formant frequencies

Lateral x-ray tracings, spectrograms and (for vowels and laterals) amplitude records are given for most sounds of Lisbon Portuguese. The x-ray films were taken at 50 frames/sec. Formant frequencies are also provided.

59 Dem'janenko, M. J. 1966

Vstupnyi Fonetyko-Hrafichnyi Kurs Fracuz'koi Movi: Laboratorii Eksperimental'noi Fonetiki

French, Russian, Ukrainian still, fps?

a,ɑ,ɑ:,i,ɔ,o,u,e,ɛ,ʃ,l,ɫ,lj,k,kj,ʃj,r,rj plural

X*

palatograms, labiograms

A two volume course in French pronunciation for Russian-speaking learners. Included are a number of x-ray tracings of French, Russian and Ukrainian taken from the literature as well as some accompanying labiograms and palatograms (not necessarily from the same speakers). Tracings included are from: Brunot and Bruneau (1933), Carmody (1937), Chlumsky (1938), Matusevich and Ljuoimova (1963), Prokopova (1958), Shcherba (1963), Suntova (1960) and Zebek (1962), some of which we have not been able to locate otherwise.

60 Dodi, A. 1970

Fonetika e Gjuhës së Sotme Shqipe. [Phonetics and the sounds of Albanian]. Pristina (Kosovo, Yugoslavia): University of Pristina.

Albanian fps

p,m,f,t,θ,n,s,ts,c,ɟ,ʃ,ɲ,k,h,l,ɫ,ɹ,r,a,i,y,u,o,e,ə,j

palatograms

Contains x-ray tracings and palatograms illustrating the sounds of Albanian.

61 Dukelski, N.I. 1960

Cercetare foneticâ experimentalâ asupra palatalizârii şi a labializârii consoanelor romînesti. Fonetica şi Dialectologie 2: 7-45.

Romanian, Russian — still

i,e,a,o,u,ɯ,ə,j,p,pj,t,ts,s,z,zj,n,nj,š,k,kj,r,l,lj,h,hj — 12

X

palatograms,photographs.

Still x-rays were taken of 12 Romanians from several different dialect areas and 1 Russian. The paper includes tracings of most of the sounds of Romanian, with usually 4 or more speakers for each sound illustrated. Palatograms for 3 speakers are also given for each segment. The photographs of the lips from the front and side are, unfortunately, unlabeled. Two Russian segments (schwa and l) are also included for comparison.

62 Dvončová, J. 1980

Fyziologická Fonetika. Bratislava: Slovenské Pedagogické Nakladatel'stvo.

Slovak

a,ä,e,i,o,u,p,t,tj,k,n,s,ʃ,l,lj,r

labiograms, palatograms, linguagrams

Some of the tracings in this book are from Dvoncová et al1969 and others from Molnár 1970. Labiograms (frontal and lateral), palatograms and linguagrams are given for most segments.

63 Dvoncová, J., G. Jenča, A. Kral 1969

Atlas Slovensk´ych Hlások. Bratislava: Vydavatel'stvo SAV.

64 Fant, G. 1960

Acoustic Theory of Speech Production, with Calculations Based on X-ray Studies of Russian Articulations. The Hague: Mouton.

Russian — still
ɨ,u,j,p,pj,m,mj,f,fj,t,tj,n,nj,s,sj,k,kj,š,č,šč,l,lj,r,rj,x — ?
L,X*

spectrograms, spectra, area functions, +

Includes tracings of a number of Russian segments. Also given are spectrograms, spectra, area functions, etc.

65 Fant, G. 1965

Formants and cavities. In E. Zwirner and W. Bethge (eds.), Proceedings of the 5th International Congress of Phonetic Sciences. Basel. Pp. 120-141. [Annotations call this Fant 1964.]

Swedish — still; tomo
ɑ,iː,eː,æː,a,ɑː,ɔ,oː,uː,yː,øː,œ,ɵ,ʉː — ?
X

Gives tracings of 14 Swedish vowels, with tomographic cuts shown for [i,u,a].

66 Fant, G. 1969

Distinctive features and phonetic dimensions. STL-QPSR 2-3 1969: 1-18.

Swedish — still
iː,eː,æː,aː,yː,øː,œ,ɑ,ʉː,ɵ,ɔ,uː,oː — ?
X*

Fant here gives reproductions of tracings (very small) of 13 Swedish vowels originally published in Fant (1961)(which we were not able to locate). These are the same tracings as in Fant (1965) with the addition of a figure showing their relation in a "spread" versus "flat" mel scale plot.

67	Feldman, D. 1972 On utterance-final [ɨ] and [u] in Portuguese. In Albert Valdman (ed.), Papers in Linguistics and Phonetics to the Memory of Pierre Delattre. The Hague: Mouton. Pp. 129-142. Portuguese(Braz.) still i,ɨ,u,ʊ ? X spectrograms Study of Brazilian Portuguese utterance-final [ɨ] and [u], noting that the two sounds are very much alike both acoustically and articulatorily (native speakers were unable to distinguish the two in a perception test.) In some dialect areas, the speakers do not distinguish articulatorily between the two phonemes, but in other dialects slight articulatory differences were noted. 4 small x-ray tracings are included as well as spectrograms of sample minimal pairs. The usefulness of the figures is greatly diminished by the fact that the author nowhere mentions which dialect is being represented (not even for the tokens used in the perception test).
68	Fónagy, I. 1976 La mimique buccale. Aspect Radiologique de la vive voix. Phonetica 33: 31-44. Hungarian ? i,e:,u: 2 X* An actor and an actress were filmed uttering 6 Hungarian phrases suggesting various emotive states. Comparisons are made of tongue shape and height differences between vowel tokens said with different emotions. Tracings given are the following: [i] -- neutral, absent-minded, joyful; [e:] -- indifferent, joyful, sad, indignant, hateful; [u:] -- neutral, joyful, menacing, ironic.
69	Forchhammer, J. 1920 Denn Menneskelige Stemme. Copenhagen: Nordisk. Danish still i,e,ɛ,æ,y,ø,œ,u,o,ɔ,ɒ,ʌ,ɑ,ə,a,m,wæ,wa,v,ŋ,ɣ,j,ʁ,n,ð,s,ʃ,n̺,ð̺,s̺,ʃ̺ 1 X* labiograms An early study giving very stylized tracings of Danish sounds, including both apical and laminal versions of some consonants.

70 Forchhammer, J. 1951

Allgemeine Sprechkunde. Heidelberg: Universitätsverlag.

i,e,ɛ,æ,y,ø,œ,u,o,ɷ,ɔ,ɯ,ɤ,ʌ,ɑ,ə,p,m,w,f,t,n,j,ð,k,ŋ,x,l,s,ʃ,r,ʀ

?
1
X*

A phonetics textbook including x-rays and labiograms of a phonetician making various sounds (not meant to represent any one language).

71 Gaprindašvili, S. 1966

Fonetika Darginskogo Yazuka (The Phonetics of the Dargi Language). Tbilisi, USSR: Mečniereba.

Dargi
i,e,a,o,u,aʕ,j,p,p:,p',b,m,v,t,s,z,ts,ts:,ts',ʃ,ʒ,tʃ,tʃ:,tʃ',k,k:,k',x,ɣ,x̟,q,q
χ,qχw,ʕ*:,ʕ*w',ʜ,ʢ,r,h

?
2
X*

kymograms,palatograms

An x-ray study of the sounds in Dargi. Two different dialects are represented in the tracings and kymograms, and often a comparison is possible. In addition, palatograms are shown of 4 dialects (one of the above and 3 others). Included are such interesting sounds as: a long pharyngeal affricate, a labio-velarized pharyngeal affricate ejective and deep pharyngeal fricatives. The affrication on the pharyngeals is symbolized here by an asterisk.

72 Gay, T. 1974

A cinefluorographic study of vowel production. Journal of Phonetics 2: 255-266.

English(Am.)
i,a,u,p,t,k

64 fps
2
X

tongue position graphs,measurements

Investigates the effects of different consonant and surrounding vowel environments on the target positions of the vowels /i,u,a/. Effects of speaking rate are also discussed. The subjects were two American English speakers who were filmed at 64 frames/sec. In addition to the x-ray films, an acoustic recording was made. The test words were of the form /pV1CV2pe/ where V=/i,a,u/ and C=/p,t,k/. No x-ray tracings as such are given. The data is presented as graphs of the position of the tongue (back-front against low-high) and tongue height and jaw opening over time. The tongue measurements are calculated from the position of a lead pellet placed approx. 2" from the tip of the tongue.

73 Gay, T. 1977a

Cinefluorographic and electromyographic studies of articulatory organization. In M. Sawashima and F.S. Cooper (eds.), Dynamic Aspects of Speech Production, pp. 85-105. Tokyo: University of Tokyo Press.

English(Am.) 60 fps
i,a,u,p,t,k 2
X

graphs of articulatory movements over time, EMG activity traces

Studies the timing of both anticipatory and "carryover" effects of coarticulation illustrated by both cineradiographic and EMG data, using nonsense words. No tracings are given. The x-ray data is in the form of graphs tracking the movements of lead pellets fixed on the surface of the tongue, jaw and lips.

74 Gay, T. 1977b

Articulatory movements in VCV sequences. Journal of the Acoustical Society of America 62.1: 183-193.

English(Am.) 60 fps
a,i,u,p,t,k 2
L

formant frequencies, graphs of tongue, lip and jaw position

A study of coarticulation and timing in VCV sequences. No x-ray tracings are shown. The data is in the form of graphs tracking the movement of lead pellets on the lips, jaw and tongue.

75 Gay, T., B. Lindblom and J. Lubker 1981

Production of bite-block vowels: Acoustic equivalence by selective compensation. Journal of the Acoustical Society of America 69(3):802-810.

Swedish still
i,a,o,u 5
L

graphs of vocal tract dimensions, formant frequencies

Discusses articulatory compensations used by speakers with a bite-block inserted to produce vowels with nearly identical formant values to those of vowels made without the bite-block. Tracings are shown of one speaker's /i/ and /u/ produced with and without the bite-block.

76	Gay, T., T. Ushijima, H. Hirose and F. Cooper 1974 Effect of speaking rate on labial consonant-vowel articulation. J.Phon. 2: 47-63. English(Am.) 64 fps i,a,u,p,w 2 X EMG records,frontal moving pictures,lip opening tables Two speakers of American English were tested for the effects of speaking rate on articulation. The test utterances were nonsense trisyllables of the form /kV1CV2pə/ and /kutVpa/ with V=/i,a,u/ and C=/p,w/. Two speaking rates, moderate and fast, were used. Simultaneous lateral x-ray films (64 frames/sec), EMG recordings of lip and tongue muscle activity and frontal moving pictures of the lips were taken. Tracings of x-rays showing the tongue dorsum contour, the mandible and the hard palate are given for one speaker depicting the mid-point of each segment in different /apV/ sequences where V=/a,i,u/ at two speaking rates. Also given are tracings of the mid portion of the dorsum of the tongue and the outline of the hard palate of two speakers for /a,i,u/ in two
77	Gendron, J-D 1962 La méthode radiographique appliquée à la comparaison des articulations vocaliques en français canadien et en français parisien. Proc. of the 4th International Congress of Phonetic Sciences, Helsinki, 1961. The Hague: Mouton. Pp. 155-166. French (Paris), (Canada) still i,y,u,ε,a,ɔ,ɑ,o,ɛ̃,œ̃,ɔ̃,ɑ̃ 2 X A comparison between the vowels of Parisian and Canadian French. The author compares his pronunciation with that of Chlumsky's (1938) Parisian subjects. The tracings are from still x-rays and the author admits his articulation may have been affected by artificially prolonging the vowels in question. For several examples, the comparison is drawn between vowels in very different environments, seemingly chosen to emphasize the differences (which are described in rather puzzling impressionistic terms). Despite these and other problems (the transcription given often indicates what the pronunciation would be if the word were pronounced as spelled, whereas both speakers actually substitute other vowels) the tracings may be of use.
78	Gendron, J-D 1966 Tendances phonétiques du français parlé au Canada. Paris: Klincksieck. French(Cdn.) still i,y,u,e,ε,ø,o,ɔ,a,ɑ,ɑ̃,ẽ,õ,ø̃,ts,dz,k,g 1 L palatography, labiograms, spectrograms, spectra, tables of articulatory measures A comparison is made between Canadian French vowels and their Parisian counterparts (from Chlumsky 1938). Discussion also includes some consonantal differences between the two dialects.

79	Gendron, J-D 1967 Le phonétisme du français canadien au Québec face à l'adstrat anglo-américain. In J.D. Gendron and G. Straka (eds.), Études de Linguistique Franco-Canadienne. Paris: Klincksieck. English(Cdn.), French (Cdn) i,ɪ,ə,ɛ,æ,u,ʊ,ʌ,ɔ,eɪ,oʊ,aʊ,aɪ,ɔɪ A study of the phonetic realization of English words borrowed into French in Canada. In an appendix x-ray tracings of Canadian English vowels are given.	still 1 X*
80	Gerber, P.H. 1907 Die Menschliche Stimme und Hygiene. Leipzig. German ɑ,i,u,y,t,n,k,ʃ Contains some early x-ray tracings of German.	still ? X*
81	Ghazeli, S. 1977 Back Consonants and Backing Coarticulation in Arabic. Ph.D. dissertation, The University of Texas at Austin. Arabic ʕ,ħ,q,χ,ʁ,tʕ,t,sʕ,s,ððʕ,rʕ,r spectrograms, tables of vowel F values, graphs of tongue position. Investigates the phonetic properties of back consonants in Arabic. Includes a number of tracings taken from a cine-x-ray film at 100 frames/sec. Other data provided are spectrograms, tables of formant values of vowels adjacent to back consonants and graphs of tongue position over time.	100 fps 1 X*

82	Giles, S.B., and K.L. Moll 1975 Cinefluorographic study of selected allophones of English /l/. Phonetica 31: 206-227. English(Am.) 150 fps l 3 X* X-ray study of (mid-western) American English /l/. Three speakers were filmed at 150 frames/sec. saying mainly real words at both "conversational" and "fast" rates, illustrating /l/ in several different environments. Composite x-ray tracings are given of the tongue body only (with no fixed reference points such as the hard palate or the teeth) and give a general indication of the overall tongue shape. Similar composite tracings are given of different vowels (unlabeled) wtih a "representative" /l/ for comparison. The remaining tracings are of one speaker only, comparing /l/'s said at different speaking rates and in different environments. In these tracings the upper teeth and hard palate are shown as well as the tongue dorsum contour.
83	Giot, J. 1977 Etude comparative de syllabes accentuées et prétoniques du français sur les plans articulatoire et acoustique. Travaux de l'Institut de Phonétique de Strasbourg 9: 89-169. French(Parisian) 50 fps p,b,m,t,d,ɲ,k,f,v,ʃ,a,e,ɛ,i 1 X formant values X-ray films at 50 frames/sec were taken of a speaker of Parisian French saying natural sentences containing the syllables /pa,ba,ta,da,ña,ñe,fe,ke,ñ˚,v˚,ʃ˚,mi,di/ in both stress and pre-stress positions. X-ray tracings are given for each segment in both stress positions, often depicting several successive frames. Some formant values are also given in the text.
84	Gruzov, L.P. 1960 Contemporary Mari Language: Phonetics. Part 1 of a 4 volume series, ed., by I.S. Galkin et al. Joskar-Ola, Marijskoe knizhnoe izdatel'stvo. Mari ? i,ɛ,a,o,u,ɨ,y,œ,t,k,s,ʂ,ɸ,ɣ,n,ɲ,ŋ,l,ɦ,j ? X* palatograms and frontal labiograms A phonetic description of the Mari language, giving x-ray tracings, palatograms and labiograms.

85	Haden, E.F. 1938 The Physiology of French Consonant Changes. Language Dissertations No. 26. French still p,b,t,d,n,s,z,l,ʒ,ɲ,k,g,i,e,ɛ,a,ɔ,u 1 X* palatograms A dissertation from the University of Chicago relating phonological changes in French to phonetic phenomena. Tracings from still x-rays are given from one speaker of segments in many different environments. Palatograms using an artificial palate and contour recontructions of the articulation on the palate are given for another speaker.
86	Hála, B. 1923 K Popisu Pražské Vyslovnosti (Studie z experimentální fonetiky). Rozpravy České Akademie Věd A Umeni. 3 #56. Czech still p,f,t,d,s,ts,j,c,ɟ,ɲ,ʃ,tʃ,x,k,l,r,ř,a,á,e,é,i,í,o,ó,u,ú 1 X* palatograms, linguagrams Includes x-ray tracings, palatograms and linguagrams of most of the sounds of Czech.
87	Hála, B. 1959 English Vowels in Phonetic Pictures. Prague.

88 Hála, B. 1962

Uvedení do Fonetiky Ceštiny: Na Obecne Fonetickém Základě. Praha: Československa akademie věd.

Czech

a,e,i,o,u,p,m,ɱ,t,n,c,ɲ,k,ŋ,f,s,ʃ,j,x,ɦ,ts,tʃ,l,lj,ɫ,w,r,ř

X*

palatograms, linguagrams, labiograms

X-ray tracings, labiograms, palatograms and linguagrams are given for most of the sounds of Czech. There is also an appendix with palatograms and linguagrams of a large number of speakers.

89 Hála, B. 1975

Fonetika v Teorii a v Praxi. Prague: Státní pedagogicke nakladatelství.

Czech, French

é

palatograms, labiograms

90 Hála, B. 1956

Nature Acoustique des Voyelles. Nákladem Karlovy University. V Praze.

Czech ?

i,e,a,o,u ?

X*

tables of resonances

The author gives tracings of the Czech vowels [i,e,a,o,u] (the same ones as in Hála and Sovak 1955), as well as tables of resonances for these and other vowels of Czech.

91 Hála, B. and M. Sovak 1955

Hlas-řeč-sluch. (Základni věci z fonetiky a logopedie). Prague: Státni pedagogické nakladatelstvi.

Czech ?

i,e,a,o,u,p,t,tj,k,m,f,s,ʃ,j,x,l,r ?

X*

palatograms, labiograms, linguagrams

Tracings are given of many of the segments of Czech. Palatograms, linguagrams and some labiograms are included as well. There is some discussion of pathological pronunciations and malformed palates.

92 Han, M-H. 1978a

Etude Articulatoire et Acoustique des Voyelles du Coréen: Analyses Radiocinématographique et Sonagraphique. Thèse de Doctorat de 3ème cycle présentée à l'Université des Sciences Humaines de Strasbourg.

93 Han, M-H. 1978b

Les voyelles du Coréen de Seoul: analyse radiocinématographique et problèmes de classement. Travaux de l'Institut de Phonétique de Strasbourg No. 10: 41-81.

Korean 64 fps

i,e,ɛ,u,o,ɔ,ɯ,a 1

X

graphs of measurements

A portion of the author's Thèse de Doctorat de 3ème Cycle and gives the results of a radiocinematographic study of Korean vowels. The subject was a speaker of the Seoul dialect, uttering real word phrases. X-ray films were taken at 64 frames/sec with synchronized sound recordings. 7 measurements were taken from the tracings after superimposing a grid. These measurements are shown graphically in addition to the tracings provided.

94	Hardcastle, W.J. 1974 Instrumental investigations of lingual activity during speech: A survey. Phonetica 29: 129-157. English(Br.) ? s 1 X* Within his survey of instrumental techniques for observation of lingual activity, the author includes one tracing of his own (British English) articulation of [s], with the location of both the center and sides of the tongue indicated.
95	Hardy, J. 1961 Intraoral breath pressure in cerebral palsy. Journal of Speech and Hearing Disorders 26.4: 309-319. English(Am.) fps æ,ʌ,u,t,ð,z 3 X* maximum oral pressure readings Discusses the relationship of velopharyngeal opening and oral pressure to intelligibility in children with cerebral palsy. Tracings showing only the position of the velum during a three syllable utterance are given for one subject.
96	Hegedüs, L. 1937 Röntgenaufnahmen von ungarischen Vokalen. Archives Néerlandaises de Phonétique Expérimentale 13: 72-77. English (Am.), German, Hungarian, Spanish still i,y,e,ɛ,ø,o,ɔ,a In an early still x-ray study, the author compares vowels in 4 languages.

97 Hetzron, R. 1969

Two notes on semitic laryngeals in East Gurage. Phonetica 19: 69-81.

Arabic ?
i,a,u,ʕ 1
X*

Included in this historical study of Semitic laryngeals are 6 very small tracings from Delattre.

98 Holbrook, R.T., and F.J. Carmody 1937

X-ray studies of speech articulations. University of California Press Publications in Modern Philology 20: 187-237.

Eng.(Br.,Am.),French,Germ.,Ital.,Polish,Portug.,Russ.,Span. still
i,ɩ,y,e,ɛ,ɛ̃,æ,œ,œ̃,a,ɑ,ɑ̃,ɔ,ɔ̃,o,ɷ,u,ʌ,β,v,f,r,ʁ,n,m,ð,θ,z,s,ç,ʒ,ʃ,x,l,ɫ,lj,λ,m, plural
n,ŋ X

Selected films from R.T. Holbrook's x-ray (still) collection are presented here by F.J. Carmody. The tracings are small and often difficult to read because so many anatomical details are supplied. Nevertheless, there is a lot of data here and it could be useful. Given are French vowels, sung at a high pitch by a soprano, spoken French vowels of three speakers and French consonants for two speakers. Tracings are given for British English (one speaker) and for American English (two speakers). Spanish segments are illustrated by two speakers. In addition, segments are shown for one speaker each from Portuguese, Italian, Polish, Russian and German.

99 Houde, R.A. 1967

A Study of Tongue Body Motion During Selected Speech Sounds. Ph.D. thesis. University of Michigan.

English(Am.) fps
u 1
L,X*

Studies the movements of the tongue body and their relationships to the phonemic representation of speech. Uses nonsense trisyllabic words with different stress placements as spoken by an American English speaker. Suggests point-parameterization as a reliable means of dealing with the physical characteristics of the articulators. Includes only one photograph of an x-ray frame and a tracing of the same.

100 Huizinga, E. 1931

Recherches sur un ventriloque néerlandais. Archives Néerlandaises de Phonétique Expérimentale 6: 66-87.

Dutch — still

i,e,y,a,o — 1

X*

Still x-ray photographs and tracings are given of a Dutch ventriloquist sustaining vowels in his normal voice and in his ventriloquist voice (i.e. with the mouth nearly shut).

101 Huizinga, E. 1932

Uber die stello, wo der Charakter des Selbstlautes Gebilde Wird. Archives Néerlandaises de Phonétique Expérimentale 17: 104-117.

still

a,i,œ,o,ɛ,u — 1

X*

The native language of the subject in this study is not given, but is assumed to be Dutch or German. The experiment was designed to show how the vocal tract compensates for fixed jaw positions. Tracings are shown of the sounds uttered both with clenched teeth and with a bite block inserted.

102 Huizinga, E. and A. Moolenaar-Bijl 1941

Kompensierung im Asatzstück bei der Bildung von Selbstlauten. Archives Néerlandaises de Phonétique Expérimentale 17: 1-8.

Dutch — still

a,i,u,t,k — 5

X

Still x-rays were taken of 5 Dutch subjects uttering /a,i,u/ in three different consonant environments. X-ray photographs are given of [a] in /ta/ and /ka/ and the [u] in /tu/ and /ku/. In addition several x-rays were made of a man using esophageal speech. Shown are chest x-rays of the esophagus at rest and during speech and this same speaker uttering [a], [i] and [u].

103	Husson, R. 1962 Physiologie de la Phonation. Paris: Masson et Cie. a,ã,i — tomo / plural / X* laryngostroboscopic image tracings, glottograph records This book on the physiology of phonation gives frontal tomograms taken of phonation performed while the subjects were on their backs with their heads fixed. Subjects were professional singers with different voice ranges (soprano to bass) who sang different vowels (usually [a]) in various registers, at various frequencies and various amplitudes. Lateral x-ray tracings are also given altering the above variables. In addition, some laryngostroboscopic image tracings and glottograph records are provided. Subjects native languages are not given.
104	Isačenko, A.V. 1947 Fonetika Spisovnej Ruštiny. Bratislava: Slovenská Akademia Vied a Umení. Russian, Slovak — still a,e,i,ɨ,u,j,m,mj,t,tj,tʃ,s,š,ś,ŝ,č,l,ɫ,k,kj,x — plural X* palatograms, labiograms Mainly concerns Russian phonetics, but a few tracings of Slovak segments are given for comparison. A few palatograms and labiograms are included.
105	Jassem, W. 1973 Podstawy Fonetyki Akustycznej. Warsaw: Polska Akademia Nauk, Instytut Podstawowych Problemów Techniki. Polish? — ? i,a,ɑ,u — 1 X* spectra, spectrograms, formant values Mainly a textbook (in Polish) on acoustic phonetics. X-ray photographs are included of four vowels. They are unfortunately very dark and difficult to read. Also includes spectra and spectrograms of most of the segments discussed as well as formant values for the vowels, nasals and laterals. Contains an extensive bibliography of acoustic phonetics.

106	Jazič, J.H. Osnovi fonetike ruskog jezika. Beograd, Naučna Kniga. Russian, Serbo-Croatian i,e,a,u,o,ə,ie,j,l,r,ʃ,tʃ,dʒ,lj,nj,x,s,sj,rj,p,pj,dj,t,tj,tʃj,žj,šj palatograms, labiograms Compares the articulation of sounds in Serbo-Croatian and Russian. Palatograms and labiograms are also included.	1977	 ? ?
107	Jones, D. An Outline of English Phonetics. New York. English(Br.) i,e,ɛ,a,u,o,ɔ,ɑ,s,ʃ palatograms, photos Some of the figures illustrating articulatory vocal tract shapes are said to be based on x-rays. Among these are the cardinal vowels, shown in two composite tracings and British English (RP) sibilants, which are supplemented by palatograms and frontal labiograms.	1922	 still 1 X*
108	Jones, D. The Pronunciation of English. 4th edition. Cambridge: The University Press. 1st edition, 1909. English i,a,ɑ,u At the beginning of the book, x-ray photographs of four cardinal vowels are reproduced.	1956	 still 1 X*

109	Jones, S. 1929 Radiography and pronunciation. Proceedings of the Society of Radiographers. The British Journal of Radiology, N.S. 2: 149-150. English (Br.), cardinal vowels — still i,e,ɛ,a,ɑ,ɔ,o,u,ʗ — 1 X*,O waveforms Transcription of a short talk on the use of radiography to study pronunciation. Includes still x-ray photographs of a speaker of British English uttering /a/ with "good" and "throaty" intonation, /a/,/~e/ ,/j/, three cardinal vowels and the Zulu post-alveolar click. Two lead chains were used during the radiography to highlight the position of the tongue. Also given are waveforms of the 8 cardinal vowels.
110	Kästner, H. 1981 Phonetik und Phonologie des Modernen Hocharabisch. Leipzig: VEB Verlag Enzyklopädie Leipzig. Arabic — ? t,tʕ,s,sʕ — 1 X* A descriptive study of the phonetics and phonology of modern standard Arabic, included because it contains 4 tracings from Marçais (1948) which we have not been able to locate otherwise. Other tracings in the book are from Delattre (1971).
111	Kent, R.D. 1970 A Cinefluorographic-Spectrographic Investigation of the Component Gestures in Lingual Articulation. PhD Thesis, University of Iowa.

112 Kent, R.D. 1972

Some considerations in the cinefluorographic analysis of tongue movements during speech. Phonetica 26: 16-32.

English(Am.) 100/150fps

i,ɪ,e,æ,ɑ,o,ɔ,u,oɪ,aɪ,p,m,t,k,ŋ 3

X*

graphs of radiopaque marker displacement

Discusses techniques for analyzing tongue movement with cinefluorography, using four radiopaque markers on the tongue dorsum. A composite tracing is given for the vowels i,u,a as well as a comparison of the three tongue shapes without reference to any fixed point. Other data include displacement patterns for the markers during various utterances and tongue body movement and velocity in the diphthong /ai/.

113 Kent, R.D. and K.L. Moll 1969

Vocal-tract characteristics of the stop cognates. Journal of the Acoustical Society of America 46.6: 1549-1555.

English(Am.) 150fps

i,ɑ,t,d,n,k,g 3

X*

articulatory measures over time

Explores differences between voiced and voiceless stop cognates in nonsense disyllables. A series of measurements were taken from the tracings and graphs of these measures over time form the data presented.

114 Kent, R.D. and K.L. Moll 1972a

Cineflurographic analysis of selected lingual consonants. Journal of Speech and Hearing Research 15.3: 453-473.

English(Am.?) 150 fps

i,u,a,g,j,d,z 2

X*

graphs of tongue and jaw displacement,composite tracings

Two speakers (probably American English, but it is not stated) were recorded on x-ray film (150 frames/sec) uttering symmetric VCV disyllables where V=i,u,a and C=g,j,d,z at moderate and rapid speech rates. The movements of three radiopaque markers on the midline of the tongue dorsum are tracked as well as the movements of the tongue apex and the mandible. Two composite tracings showing the tongue dorsum and the hard palate only for each speaker and three vowels are given. The rest of the data is in the form of graphs of tongue and jaw displacement for the different subjects, segments and speech rates.

115 Kent, R.D. and K.L. Moll 1972b

Tongue body articulation during vowel and diphthong gestures. Folia Phoniatrica 24: 278-300.

English(Am.) 100fps

i,ɛ,æ,ɑ,o,j,aɪ,ɔɪ,ɔɹ 2

X*

graphs of displacement of radiopaque markers, jaw movement

Studies vowel to vowel, diphthong to vowel and diphthong to diphthong tongue and jaw movements. Most of the data is presented in the form of graphs of the displacement of two radiopaque markers on the tongue.

116 Kent, R.D. and K.L. Moll 1975

Articulatory timing in selected consonant sequences. Brain and Language 2: 304-323.

English(Am.) 150fps

s,p,r,l,k,w 3

X*

plots of temporal intervals between articulatory events

A study of the consonant sequences /spr/, /spl/ and /skw/ in various linguistic environments, to see if the articulatory timing varied according to environment. Data is in the form of plots of temporal intervals between specified articulatory events.

117 Kent, R.D. and R. Netsell 1971

Effects of stress contrasts on certain articulatory parameters. Phonetica 24:23-44.

English (Am) 1-150fps

i,ɪ,o,æ,ɔɹ 2

X*

measurements of articulatory parameters

A study of articulatory differences in noun vs. verb as well as emphatic stress contrasts in English. Radiopaque markers on the tongue were tracked. No tracings are provided.

118 Kent, R.D., and R. Netsell 1975

A case study of an ataxic dysarthric: cineradiographic and spectrographic observations. Journal of Speech and Hearing Disorders 40: 115-134.

English(Am.) 28fps

i,æ,ɑ,u,ɚ,g 1

X*

spectrograms, graphs of articulatory movements, fundamental frequency contours

Studies the articulation of a subject with ataxic dysarthria. Tracings are given of sustained vowel sounds and the vowel and final consonant in the word DOG. The temporal structure of a sentence is compared to the same utterance by a normal speaker. Movements of the velum, tongue, jaw and lower lip are tracked over time for sentence length utterances. Fundamental frequency contours are also examined.

119 Kent, R.D., R. Netsell, and L.L. Bauer 1975

Cineradiographic assessment of articulatory mobility in the dysarthrias. Journal of Speech and Hearing Disorders 40: 467-480.

English(Am.) 28fps

u,a,æ,aɪ,g,j,d,n 8

X*

Four normal and four dysarthric subjects were x-ray filmed uttering isolated vowels and full sentences of text to determine the range of mobility of two points on the tongue (radiopaque markers), and of the jaw and lower lip. Figures are in the form of composite x-ray tracings depicting tongue body movement from one segment to another as well as ranges (a composite of all utterances) of movement of the radiopaque markers. Most of the data shown is of the dysarthric subjects.

120 Kim, C.-W. 1967

Cineradiographic study of Korean stops and a note on "aspiration". Quarterly Progress Report Research Laboratory of Electronics, M.I.T., 86: 259-272.

Korean 50fps

p*,p,p^h,t*,t,t^h,k*,k,k^h,i,e,a,d,g,r 1

O

graphs of articulatory measurements over time

A study of the three voiceless consonant types in Korean: "fortis", "lenis" and aspirated. Data is in the form of graphs of articulatory measurements (pharynx width, larynx height, distance between the vocal folds) from both lateral and frontal x-rays. The asterisk here symbolizes the fortis stops.

121 Kiritani, S. 1977

Articulatory studies by the x-ray microbeam system. In M. Sawashima and F.S. Cooper (eds.), Dynamic Aspects of Speech Production. Tokyo: University of Tokyo Press. Pp. 171-194.

Japanese 130fps

i,e,a,o,u,b,t,d,s,z,c,j,sj,k,g 1

L

graphs of tongue pellet trajectories and time functions, formant frequencies

A description of the x-ray microbeam system at the University of Tokyo and a pellet tracking experiment of nonsense syllables. Data is given in the form of graphs of all 5 tongue pellet trajectories simultaneously and the time functions for the x and y coordinates for each pellet individually. Formant frequencies over time are also graphically displayed.

122 Kiritani, S. 1986

X-ray microbeam method for measurement of articulatory dynamics--techniques and results. Speech Communication 5.2: 119-140.

123 Kiritani, S., Y. Tateno, T. Iinuma and M. Sawashima 1977

Computer tomography of the vocal tract. In M. Sawashima and F.S. Cooper (eds.), Dynamic Aspects of Speech Production. Tokyo: University of Tokyo Press. Pp. 203-206.

Japanese still

i,a 1

L

-

A method of computer x-ray tomography is explained and examples of two vowels are given, illustrating the use of tomography to determine cross-sectional area of the vocal tract.

124 Kirkpatrick, J.A. and W.R. Omsted 1959

Cinefluorographic study of pharyngeal function related to speech. Radiology 73: 557-559.

125 Kiss, G. 1981

A dinamikus röntgenográfiai vizsgálat számítógépes programja (The computer program for dynamic radiographic examinations). Magyar Fonetikai Füzetek (Hungarian Papers in Phonetics), No. 7: 56-58.

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-

L

A description in Hungarian (but with figures) of the computer system used in the dynamic radiographic analyses in Bolla's research.

126 Kojima, G. 1971

Problèmes de coarticulation en Japonais. Travaux de l'Institut de Phonétique de Strasbourg 3: 158-172.

Japanese(Tokyo) ?

ʃ,s,z,ɯ,ɯ̥,i̥ 1

L

spectrograms

An acoustic study of coarticulatioin in Tokyo Japanese. Includes 4 x-ray tracings of one subject, illustrating sibilants and voiceless vowels. Spectrograms are given of these and other segments in real word phrases.

127 Koneczna, H. and W. Zawadowski 1956

Obrazy Rentgenograficzne Glosek Rosyjskich. Warsaw: Panstwowe Wygawnictwo Naukowe.

Russian ?

i,e,a,o,u,ɨ,ə,j,p,pj,b,bj,m,mj,f,fj,v,vj,t,tj,d,dj,n,nj,ts,s,sj,z,tʃ,ʃ,ʒ,ʒj,k,k 4

j,g,gj,x,xj,ɣ,r,rj,ɫ,lj X*

palatograms

Contains tracings of all Russian consonants and vowels (in stressed, unstressed and reduced forms and in environments before and after palatalized consonants), spoken by up to 4 subjects, in isolated syllables and in real words. Palatograms from published sources are also reproduced, and discussed in connection with the x-ray data.

128 Korlén, G. and B. Malmberg 1960

Tysk Fonetik. Lund: Gleerups.

German ?

i,ɪ,e,ɛː,ɛ,y,ʏ,ø,aː,a,ə,o,ɷ,u,s,ʃ,ç,x ?

X*

spectrograms, palatograms

Tracings of German vowels and some fricatives are given as well as spectrograms of the vowels and a few palatograms. The x-rays are credited to several other sources: F. Strenger, E.A. Meyer and H.H. Wängler.

129 Kuehn, D.P. 1973

A Cinefluorographic Investigation of Articulatory Velocities. Ph.D. Dissertation, University of Iowa Department of Speech Pathology and Audiology

English(Am.) still/150fps

i,a,u,p,t,k,f,s,l 5

L

graphs of velocity, displacement rate and oral structure size

17 subjects were initially screened for size of oral structures by lateral and antero-posterior still x-rays. 5 of these were chosen (representing a range of sizes) for the high speed cinefluorographic films which recorded the movement of 5 radiopaque markers on the tongue and lips during nonsense syllables and disyllables at two different speaking rates. The relationships between oral cavity size, speaking rate, phonetic context and articulatory velocity and displacement are discussed. There are no actual tracings. All data is graphically displayed.

130 Kuehn, D.P. and K.L. Moll 1976

A cineradiographic study of VC and CV articulatory velocities. J. Phon. 4: 303-320.

English(Am.) 150fps

i,a,u,p,t,k,f,s,l,h 5

O

graphs and tables of displacement and velocity

Mono and disyllabic nonsense utterances were x-ray filmed at 150 frames/sec at two speaking rates. The movements of radiopaque markers on the lips and tongue were tracked to study the relationship between articulatory velocity or displacement and tongue or jaw size. No tracings are given.

131 Laczkowska, M. 1961

Concerning the function of the velum. Folia Phoniatrica 13: 107-111.

?

a 3

X*

Studies the function of the velum in the speech of boys between the ages of 7 and 12. Uses both normal and pathological subjects (including stuttering, dyslalia, and hypernasality). The author found marked differences in the velar function in normal and pathological cases. X-rays are shown of three boys: one who stuttered, one with hypernasality and one who had difficulty producing velar stops; all producing a sustained [a] vowel.

132 Ladefoged, P. 1964

A Phonetic Study of West African Languages. Cambridge: University Press.

Igbo, Kutep, Ngwe still, fps

a,ɓ i,e,ɛ,u,ɷ,ɔ,æ,ɐ,u,y,ɯ,ɣ,ʌ,z͡v ?

X*

laminagrams

Includes tracings from cine-x-rays of Igbo , Ngwe and both lateral and frontal laminagrams of Kutep [zv] from still x-rays.

133 Ladefoged, P., J. DeClerk, M. Lindau, and G. Papçun 1972
An auditory-motor theory of speech production. UCLA Working Papers in Phonetics 22:48-75.

English(Am.) 120fps
i,ɪ,e,ɛ,æ 6
L,W

spectrogram, graphs of articulatory measurements

A composite tracing showing each of the five front vowels is given for each speaker. In addition, graphs of articulatory measurements (tongue height, mandible height, tongue lift relative to mandible, tongue root advancement and hyoid height), one spectrogram and tables of statistical analyses for the articulatory measurements are provided. The x-rays of the back vowels which were taken at the same time, but not included in the paper are available in the lab.

134 Liljedahl, N.A. 1933
Bidrag till kännedomen om S-ljuden i Göteborg deras uppkomst ock bildningssätt. Svenska Landsmål ock Svenskt Folkliv, Vol H-207: 27-69.

Swedish still
ɧʃ plural
X

photographs of lips

Describes the six /S/ variants as found in the Swedish dialect spoken in Göteborg. Still x-rays were taken of pupils in the city schools and supplemented with photographs of the lips.

135 Lindau, M. 1975
Features for vowels. UCLA Working Papers in Phonetics 30.

Akan, Ateso, Igbo (Umuchu), Ijo(Okrika) still, fps
i,ɪ,e,ɛ,u,ʊ,o,ɔ,æ,a,ɜ plural
W,X

F charts, graphs of articulatory dimensions

An investigation into the phonetic correlates of vowel harmony in African languages. Includes numerous x-ray tracings of vowels in four different languages. Tracings from still x-rays are given for Akan, Umuchu Igbo , Okrika Ijo, and Ateso (one speaker each). X-ray cinematography at 24 frames/sec was used for 4 Akan speakers (3 Akyem dialect and 1 Ashanti dialect). In addition, formant charts and graphs of articulatory dimensions are provided for the vowels discussed.charts and graphs of articulatory dimensions are provided for the vowels discussed.

136 Lindau, M. 1979

The feature expanded. Journal of Phonetics 7: 163-176.

Akan — 24fps

i,ɪ,e,ɛ,o,ɔ,u,ʊ — 4

X,O

formant chart, tables of statistical measures

Two composite tracings are given for each of the four subjects showing front and back vowels of the two vowel harmony sets in Akan. Also provided are a formant chart, tables of statistical measures and data from an articulatory model.

137 Lindblom, B. and J. Sundberg 1969-70

A quantitative theory of cardinal vowels and the teaching of pronunciation. STL-QPSR 2/3 1969. Pp. 19-26.

Swedish — ?

i,e,ɛ,æ,u,o,œ,a,y,ʉ,ø — ?

L

In a paper describing their articulatory model, the authors include x-ray tracings showing the contour of the tongue and the mandible for the Swedish vowels [i,e,ɛ,æ,u,o,œ,a,y,ʉ,ø].

138 Lindqvist, J., M. Sawashima, and H. Hirose 1973

An investigation of the vertical movement of the larynx in a Swedish speaker. Annual Bulletin 7. Research Institute of Logopedics and Phoniatrics, University of Tokyo.

139 Macmillan, A.S., and G. Keleman 1952

Radiography of the supraglottic speech organs, a survey. A.M.A. Archives of Otolaryngology 55: 671-688.

X

140 MacNeilage, P.F. and G.N. Scholes 1964

An electromyographic study of the tongue during vowel production. Journal of Speech and Hearing Research 7: 209-232.

fps

i,ɪ,e,ɛ,æ,ɑ,ʌ,ɔ,o,ʊ,u,aɪ,ɔɪ,aʊ,ɚ,aɹ,oɹ 1

O,X*

EMG record for tongue

This EMG study also includes x-ray tracings from the same speaker at a different time. The native language of the speaker is not mentioned, although it is assumed to be American English since r-colored vowels are included in the data. Film speed is also not given. For each segment a tracing is given showing only the tongue contour and the teeth, along with the EMG activity at 13 electrodes placed along the tongue.

141 Malmberg, B. 1963

Spansk Fonetik. Lund: Gleerups.

Spanish still

i,e,a,o,u,ʎ,j,x

X*

palatograms, linguagrams

This book no Spanish phonetics gives x-ray tracings of Spanish [i,e,a,o,u,F,j,x] as well as palatograms and a few linguagrams.

142	Malmberg, B. 1969 Phonétique Française. Malmö: Hermods. French still i,e,ɛ,a,y,u,o,ɔ,ɔ̃,ʁ,s,ʃ 1 A manual of French pronunciation for non-native teachers of French. Includes a number of x-ray photographs which are sometimes difficult to read.
143	Marçais, P. 1948 l'Articulation de l'emphase dans un parler arabe maghrébin. Annales de L'Institut des Etudes Orientales de l'Université d'Algier 7: 5-28. Arabic
144	Martens, P. 1970 Optische Unterstützung akustischer Sprachsignale. In B. Hála, M. Romportl and P. Janota (eds.), Proceedings of the Sixth International Congress of Phonetic Sciences (Prague 1967). Prague: Academia. Pp. 613-616. German ? i,ɪ,e,ɛ,ɔ,o,u,ω,y,p,t,k,g,ç,x ? X photographs Included in are x-ray tracings, palatograms and frontal photographs of the lips during the articulation of the German sounds [i,I,e,˚,O,o, ,u,y,p/b,t/d,k,g,ç,x]. Also included are the above illustrations with the addition of lateral labial photographs for the German segments [e,E] and tongue-tip vs. blade articulations of [t] and [d].

145 Matusevič, M.I. and N.A. Ljubimova 1963

Al'bom Artikuljacij Zvukov Russkogo Jazyka. Moscow: Uzd-vo Universiteta Druzby Narodov im. Patrisa Lumumby, M.

146 Matusevič, M.I. and N.A. Ljubimova 1964

Articuljatsits Russkix Zvukov Pod Udareniem Na Osnove Rentgenografičeskix Dannyx. Voprosy Fonetiki. Učenye zapiski No.325. Serija Filologičeskix Nauk 69. pp.37-44. Leningrad: Izdatel'stvo Leningradskogo Universiteta.

Russian — still

t,tj,n,nj,s,sj,š,šj,l,lj,r,rj,i,ɨ,e,a,o,u — 1

X*

X-ray tracings are given of Russian palatalized and non-palatalized consonants as well as 6 vowels.

147 Maxmudov, A. 1967

Labializovannaja O v sovremennom uzbekskom jazyke. Zeitschrift fûr Phonetik 20:335-338.

Uzbek — still

ɔ — 1

X

labiogram, formant frequencies, spectra

Description of the articulation of modern Uzbek /o/. One x-ray tracings, a labiogram, formant frequencies and spectra are given for the vowel in question.

148 Mazlovà, V. 1949,1967

Vijslovnost na Zábřežsku (Pronunciation in the Vicinity of Zabřek). Prague.

149 Miletič, B. 1933

Izgovor srpskochravataskich glasova (Pronunciation of Serbocroatian Sounds). Belgrade.

Serbocroatian

150 Miletič, R. 1960

Osnovi Fonetike Srpskog Jezika (Phonetics of the Serbian Language). Beograd: Naučna Kniga.

Serbocroatian

a,e,i,o,u,f,j,l,lj,r,s,š,x,m,t,k,ŋ,nj,ts,tʃ,dʐ 2?

X*

palatograms, labiograms

A phonetic description of Serbo-Croatian. Includes tracings of most segments. Palatograms from two speakers are reproduced as well as labiograms of the vowels.

151 Miller, E.R. 1959

Cinefluorography in practice. Radiology 73: 560-564.

152 Mkhitarian, T. 1959

Fonetika V'etnamskogo Iazyka. Moscow: Izdatel'stvo Vostocnoj Literatury.

Vietnamese(North)

i,e,ɛ,a,ə,ʌ,o,ɔ,ω,u,ɯ,ʉ,j,w,p,m,d,t,th,z,s,n,l,ɲ,g,k,kʰ,x,ŋ ?

X*

labiograms

Both x-ray tracings and labiograms are given to illustrate the sounds of a North Vietnamese dialect.

153 Moll, K.L. 1960

Cinefluorographic techniques in speech research. Journal of Speech and Hearing Research 3.3: 227-241.

English(Am.)

i,a,t,n,s 2

X*

Deals with x-ray techniques and procedures in speech research. No actual tracings are shown, only graphs of measurements (e.g. extent of velo-pharyngeal contact, distance from end of velum to pharyngeal wall, distance of tongue to alveolar ridge, incisal opening) from tracings.

154 Moll, K.L. 1962

Velopharyngeal closure in vowels. Journal of Speech and Hearing Research 5.1: 30-37.

English(Am.) 24 fps

a,æ,i,u,t,d,s,z,tʃ,dʒ,n,l 10

X*

tables of measurements

Examines velopharyngeal closure in 4 vowels /a,æ,i,u/ in the context of 8 different consonants: /t,d,s,z,tS,dZ,n,l/. 10 speakers of American English were filmed at 24 frames/sec and measurements were taken from the resulting x-ray films. Measurements include: velar height from a fixed reference line, extent of velopharyngeal contact and velum-pharynx distance. No tracings are given. Tables of statistical evaluations of the measurements are the only data provided.

155 Moll, K.L. 1965

Photographic and radiographic procedures in speech research. ASHA Reports 1: 129-139.

English(Am.)

X*

156 Moll, K.L. and R.G. Daniloff 1971

Investigation of the timing of velar movements during speech. Journal of the Acoustical Society of America 50:2(2):678-684.

English (Am.) 150fps

4

L

graphs of measurements over time

A study of timing and coarticulation in movements of the velum in phrases with both nasal and non-nasal segments. No x-ray tracings are provided. Data is in the form of a graph of measurements of velar movement over time and frequency of occurrence of velar movements at specified times in the utterance.

157	Moll, K.L. and T.H. Shriner 1967 Preliminary investigation of a new concept of velar activity during speech. Cleft Palate Journal 4.1: 58-69. English(Am.) X*
158	Molnár, J. 1970 A Magyar Beszédhangok Atlasza. Budapest: Tankönyvkiadó.
159	Monnot, M. and M. Freeman 1972 A comparison of Spanish single-tap /r/ with American /t/ and /d/ in post-stress intervocalic position. In Albert Valdman (ed.), Papers in Linguistics to the Memory of Pierre Delattre. The Hague: Mouton. Pp. 409-416. English (Am.), Spanish 24 fps a,ə,e,i,r,ɾ 1 X spectrograms Seeks to equate the American English intervocalic tap with the single spanish /r/. X-ray films were taken at 24 frames/sec of one speaker each of American English and Spanish. In addition, spectrograms were made from an acoustic recording of three speakers of each language.

160	Navarro Tomás, T. 1916 Siete vocales españolas. Revista de Filología Española 3: 51-62. Spanish still i,e,ɛ,a,o,ɔ,u 1 X palatograms, articulatory measurements An early study of the five phonemic vowels in Spanish plus two allophones. Tracings and a palatogram are given for each vowel. In addition, there is a table of articulatory measurements taken from the x-rays.
161	Netsell, R. and R.D. Kent 1976 Paroxysmal ataxic dysarthria. Journal of Speech and Hearing Disorders 41: 93-109. English(Am.) 24 z,b 1 X graphs of articulatory measurements over time, spectrograms Cinefluorographic films were made of a subject with paroxysmal ataxic dysarthria during both normal and dysarthric utterances of the same segments. Differences in articulatory placement, timing and ranges are illustrated by graphs of articulatory measurements over time during the utterance of the sentence "Please buy me that cute little dog." A composite tracing of normal and dysarthric utterances of /z/ and /b/ and spectrograms of the spoken digits "1,2,3" are also given.
162	Novák, A. 1972 The voice of children with Down's Syndrome. Folia Phoniatrica 24: 182-194. Czech ? a,e 62 X* spectrograms, graphs of articulatory measures Compares the articulation of children with Down's Syndrome (32 subjects) to that of mentally retarded children without Down's Syndrome (20 subjects) and normal children (10 subjects).

163	Ohman, S. 1967 Numerical model of coarticulation. Journal of the Acoustical society of America 41:2 pp.310-320. Swedish 48fps a,u,d,g 1 L The output of the author's numerical model was compared to real x-ray tracings of a Swedish speaker uttering nonsense VCV disyllables. These tracings, of the consonants /d/ and /g/ in various vowel environments, are shown along with the model's calculated vocal tract shapes.
164	Öhman, S.E.G. 1965 X-ray studies of articulatory dynamics. Proceedings of the 5th International Congress of Phonetic Sciences, Munster 1964 (Bassel-New York), pp. 16-23.
165	Ohman, S.E.G. 1966 Coarticulation in VCV utterances: spectrographic measurements. Journal of the Acoustical Society of America 39: 151-168. Swedish fps y,a,u,d,g 1 O,X spectrograms, formant frequencies Although mainly a spectrographic study of coarticulation in Swedish (with short mention of both American English and Russian) it also includes some small x-ray tracings of the Swedish subject's production of /d/ and /g/ in three vowel contexts.

166	Ohnesorg, K. and O. Švarn´y Etudes Expérimentales des articulations chinoises. Československé Akademie Věd: Rozpravy, Vol. 65, No. 5. Prague: Czech Academy. Chinese i,y,ɑ,a,u,ə,uo,ɿ,ʅ,t,n,ts,s,l,tɕ,ɕ, tṣ,ṣ,ɹ,ɻ,k,ŋ,χ palatograms, linguagrams A study of articulations in six Chinese dialects: Beijing, Tianjin, Canton, Shensi, Sichuan and Shandong. Included are x-ray photographs, tracings, palatograms and linguagrams. The French text includes detailed discussion of each segment and a comparison of its articulation from one dialect to another (or in this case, one speaker to another, since there is only one speaker representing each dialect).	1955 still 1 X*
167	Oliverius, Z.F. Fonemika Russkogo Jazyka. Prague: Státní Pedagogické Nakladatelství. Russian i,e,a,u,ɨ,t,tj,l,lj,s,sj,f,fj,m,mj,k,kj,ž palatograms, formant frequencies Includes x-ray tracings and palatograms of many of the consonants and vowels of Russian, comparing palatalized and non-palatalized consonants.	1974 ? 1 X*
168	Ondráčková, J. Artikulace českyéh zpivanych Samohlásek. Dissertation. Czech	1960

169	Ondráčková, J. 1961 The movement of the tongue and the soft palate in the singing of vowels. Folia Phoniatrica 13: 99-106. Czech — fps i,é,u — 1 X* Introduces the technique of serial radiography for phonetic purposes. Shown are photographs of x-ray frames of three Czech vowels, two sung, one spoken.
170	Ondráčková, J. 1964 Rentgenologicky Vyzkum Articulace Českych Vokálu. Prague: Nakladatelstvi Československé Akademie Ved. Czech — still/fps i,e,a,o,u — 4 X*,L intensity traces Czech sung, spoken and whispered vowels are examined by several different x-ray methods: static radiography, serial radiography and cineradiography. Tracings from four speakers are given. English translation is Ondrácková (1973).
171	Ondráčková, J. 1973 The Physiological Activity of the Speech Organs: An Analysis of the Speech Organs During the Phonation of Sung, Spoken and Whispered Czech Vowels on the Basis of X-ray Method. The Hague: Mouton. Czech — still/fps i,e,a,o,u — 4 X*,L intensity traces English translation of Ondrácková (1964).

172	Pačesová, J. 1969 Fonetika a Ortoepie Češtiny. Brno: JAMU Czech fps b,m,v,d,n,z,ts,ɟ,ɲ,ʒ,tʃ,g,ŋ,j,x,h,l,r,ř,a,e,i,o,u 1 X* labiograms, palatograms X-ray tracings, palatograms and labiograms of most of the sounds of Czech.
173	Painter, C. 1973 Cineradiographic data on the feature "covered" in Twi vowel harmony. Phonetica 28: 97-120. Twi 24 fps i,ɩ,e,ɛ,æ, a,ã,o,ɔ,u,ũ,ɷ 1 X* graphs of measurements Discusses the feature "covered" in Twi vowel harmony in the light of x-ray films of one speaker of the Kwæhu dialect. The films were taken at 24 frames/sec while the subject uttered real word disyllabic phrases. Tracings are given with a superimposed grid which makes them rather difficult to read. Another tracing is a composite of all 10 oral vowels showing the tongue dorsum, the hard palate and the back wall of the pharynx. Other data includes graphical and tabular representations of measurements taken from the x-rays.
174	Panconcelli-Calzia, G. 1924 Die Experimentelle Phonetik in Ihrer Anwendung auf die Sprachwissenschaft. Berlin: Verlag von Walter de Gruyter & Co. Kate, Nama, Zulu still k͡p,g͡b,qχ,l,ʗ 1 X* Includes four x-ray photographs (rather hard to distinguish, especially in a photocopied version) of 1) labio-velar kp/gb in Kate I(New Guinea), 2) a Zulu uvular africate qX, 3) a retroflex I from either the Dutch West Indies or again from Kate, and 4) a palatal click C from Nama (Hottentot).

175 Panov, M.V. 1967

Russkaja Fonetika. Moscow: Prosveščenie.

Russian still/fps

ts,tʃj,x,xj,j,a,o,e,u,i,ɨ,l,lj plural

X*

palatograms, spectra, formant frequencies

The vowels are given in several different palatalized and non-palatalized environments. X-rays are from Koneczna and Zawadowski 1956, Matusevíc and Ljubimova 1964, Skalozub 1963 and Žinkin 1958.

176 Parmenter, C. and S.N. Treviño 1932a

Vowel positions as shown by x-ray. The Quarterly Journal of Speech 18: 351-369.

English (Am.), Spanish(Am.) still

i,ɪ,e,ɛ,æ,a,ɔ,o,ʊ,u plural?

X*

Early still x-rays of American English and Spanish are shown in this article refuting Russell's (1928) claim that there are no consistent tongue positions for vowels, even within a single speaker. They show that, in fact, Russell's problem stems from the fact that his subjects moved and the x-rays were taken from different angles. As an example, tracings of [u] pronounced with the chin out and the chin in are given. The authors describe a device for holding the head still during filming and give the results of their vowel study. Composite tracings are shown comparing either the same or different vowels for a single speaker.

177 Parmenter, C. and S.N. Treviño 1932b

An x-ray study of Spanish vowels. Hispania 15: 483-96.

Spanish(Am.) still

i,e,ɛ,a,ɑ,o,ɔ,u ?

X

Composite tracings from still x-rays are given of various combinations of 8 different vowels in Mexican (Texas) Spanish.

178	Parmenter, C.E., and C.A. Bevans 1933 Analysis of speech radiographs. American Speech 8.3: 44-56. English(Am.) — still i,ɪ,e,ɛ,æ,ɑ,ʌ,ɔ,o,u,ʊ — ? X* Provides tracings of still x-rays of vowels in American (Chicago) English. Composite tracings comparing two of these vowels at a time are also given.
179	Parmenter, C.E., S.N. Treviño and C.A. Bevans 1933 The influence of a change in pitch on the articulation of a vowel. Language 9(1): 72-81. English (Am.), French, Spanish — still e — ? X In this early x-ray study, still x-rays were taken of speakers of American English, Spanish and French sustaining each of 5 vowels associated with real words in their language. Each vowel was said on both a high (256 HZ) and low (128 Hz) pitch. Among the changes noted in going from low to high pitch were: raising of the larynx, expansion of the lower pharynx and contraction of the upper pharynx, and raising of the epiglottis and hyoid bone. These changes varied in different vowel environments. Only one composite tracing, that of Spanish [e] at two pitches, is given, as well as a photograph of the x-ray of Spanish [e] on the lower pitch.
180	Perkell, J.S. 1969 Physiology of Speech Production: Results and Implications of a Quantitative Cineradiographic Study. Res. Monograph No.53. Cambridge, MA: The M.I.T. Press. English(Am.) — 45fps k,p,z,s,d,t,ɛ,æ,ɑ,ɪ,i,ʊ,u — 1 X*,L spectrograms, measurements Tracings of some of the x-rays on which this book is based are given in Appendix B. The films were made at 45 frames/sec and the subject was a speaker of American English. Tracings are from the midpoint of obstruent segments in utterances of the form h 'C' and of vowel segments in utterances of the form h 'tV. Accompanying each tracing is a spectrogram of the utterance and 17 different vocal tract measurements over time taken from successive frames of the x-ray film.

181 Pétursson, M. 1968-69

Les consonnes occlusives palatales [kh,g] en islandais. Travaux de l'Institut de Phonétique de Strasbourg No.1: 1-13.

Icelandic

182 Pétursson, M. 1969-70

Le système vocalique de l'Islandais à partir de l'analyse radiocinématographique. Travaux de l'Institut de Phonétique de Strasbourg No. 2: 1-31.

Icelandic

183 Pétursson, M. 1971a

Etude de la réalisation des consonnes islandaises th,∂,s, dans la prononciation d'un sujet islandais à partir de la radiocinématographie. Phonetica 23: 203-216.

Icelandic ?

θ,ð,s,s̄ 1

X

palatograms

X-ray tracings and palatograms are shown to illustrate the differences and similarities between Icelandic tip and blade alveolar fricatives. Tracings are given from one Southern Icelandic speaker. Only the upper two-thirds of the oro-nasal cavity is visible on the tracings.

184	Pétursson, M. 1971b Polymorphisme de la consonne L en islandais moderne; Examen expérimental à partir de l'analyse radiocinématographique. Travaux de l'Institut de Phonétique de Strasbourg No. 3: 120-146. Icelandic 50 fps l,l̥ ? L palatograms A study of the variants of /l/ in modern Icelandic of which x-ray films wre taken at 50 frames/sec. 16 composite tracings of successive frames are given of [l] and [l] in various environments, resulting in three major variants: dental, alveolar and alveo-prepalatal. Two palatograms are also provided as well as a table of articulatory measures taken from the x-rays.
185	Pétursson, M. 1972 La préaspiration en islandais moderne. Examen de sa réalisation phonétique chez deux sujets. Studia Linguistica 26(2): 61-80. Icelandic fps a,ɔu,ɛ 2 X* oscillogramsof audiotraces and oral airflow The author studied the so-called "preaspirated" stops in Icelandic through the medium of oscillograms of audiotraces from microphones at the larynx, nose and mouth and oral airflow for two speakers (one from southern and one from eastern Iceland) and x-ray motion pictures of the southern Icelandic speaker. The author concludes that what has been called preaspiration is actually a cluster of [h] + stop. Tracings of the upper two-thirds of the oral cavity (the lower part of the pharynx is not visible) for 5 successive frames of each of 3 vowels preceding "preaspirated" stops, [a,Ou,ˇ] are given.
186	Pétursson, M. 1973 Quelques remarques sur l'aspect articulatoire et acoustique ds constrictives intrabuccales islandaises. Travaux de l'Institut de Phonétique de Strasbourg No. 5: 79-99. Icelandic ? θ,ð,s,s̄,l̥,lj̥,j̥,ç,x,ɣ,h ? L spectrograms Describes the Icelandic intraoral constrictives using x-rays and spectrograms. Tracings are given for [p,∂,s,s',l,lj,j,d,s,R,h] in various environments.

187	Pétursson, M. 1974 Peut-on interpréter les données de la radiocinématographie en fonction du tube acoustique à section uniforme? Phonetica 29: 22-79. Also in Travaux de l'Institut de Phonétique de Strasbourg No. 4: 18-111 (1972). Icelandic — 50 fps i,ɩ,e,y,ø,u,o,a,ei,øi,ai,ou,au — 1 X* spectrograms w/ intensity tracing, f tables, tables of measurements The title of this paper gives no clue that it is actually a very thorough study of the vowels in modern Icelandic. One subject (a speaker of the Reykjavík dialect) was filmed at 50 frames/sec with a synchronous acoustic recording. The texts were real word phrases chosen to put the vowels in as similar a context as possible. For each of the vowels are given a lateral x-ray tracing composing of three different frames, a spectrogram with intensity tracing and a table of various articulatory measurements and formant values. Each of the vowels and diphthongs listed has both long and short varieties.
188	Pétursson, M. 1974b Les Articulations de l'Islandais à la lumière de la radiocinématographie (Société de Linguistique de Paris No. 68). Paris: Klincksieck. Icelandic — 50fps i,ɩ,e,ʏ,ø,u,o,a,a,ei,øi,ai,au,ou,pʰ,p,m,f,v,m̥,tʰ,t,θ,ð,n,l,lj,r,s,sj,nz,cʰ,c,ɲ,j, — 1 ç,kʰ,k,ŋ,x,ɣ — L palatograms, audio waveform at larynx, nose and mouth, and oral airflow traces. A study of the sounds of Icelandic (mainly as spoken in the south) with tracings given of each segment over time. In addition, palatograms and some audio and airflow traces are supplied. Short and long forms of most of the vowels and diphthongs are given.
189	Prokopova, L.I. 1958 Prigolosni Fonemi Sucasnoe Ukraens'koe Literaturnoe Movi. Kiev: Ukrainian — ? n,nj,š,s,sj,i,j,ç,x,d,dj,t,č — plural X* palatograms, duration measurements, acoustic measurements Tracings are given of selected Ukrainian consonants with palatograms for nearly every segment covered.

190	Puppel, S., J. Nawrocka-Fisiak, H. Krassowska 1977 A Handbook of Polish Pronunciation. Warsaw: Panstwowe Wydownictwo Naukowe. Polish ? i,ι,e,a,o,u,p,b,t,d,k,g,c,ɟ,f,v,s,z,š,ž,ś,ź,l,m,n,j,w,x 1 L labiograms A guide to Polish pronunciation which includes what are presumed to be x-ray tracings of many of the sounds of Polish, as well as labiograms of the vowels.
191	Putnam, A.H.B., and R.L. Ringel 1976 A cineradiographic study of articulation of two talkers with temporarily induced oral sensory deprivation. Journal of Speech and Hearing Research 19: 247-266. English (Am.) 60fps n 2 X graphs and tables of articulatory measures Compares normal speech with speech when a trigeminal nerve-block anesthesia has blocked sensation to all oral articulators except the jaw. Two composite tracings are given showing each subject's normal and blocked articulation of the segment /n/ in the word "soon". Changes in other segments are given in the form of tables and graphs.
192	Quilis, A. 1964 Datos fisiologico-acusticos para el estudio de las oclusivas españolas y de sus correspondientes alofonos fricativos. Homenajes: Estudios de Filologia Española 1:33-42. Spanish 50fps p,b,t,d,k,g,β,γ,ð 1 X* spectrograms A study of Spanish stops and fricatives. Tracings of each segment are given from a film of connected speech taken at 50fps. Most segments are shown in a variety of contexts. Some spectrograms are also included.

193 Quilis, A. 1981

Fonética Acústica de la Lengua Española. Madrid: Biblioteca Románica Hispánica.

Spanish ?

i,e,a,o,u ?

X*

spectrograms

Included in this thorough treatment of the acoustic phonetics of Spanish are x-ray tracings of the Spanish vowels [i,e,a,o,u] accompanied by spectrograms. The x-rays are of the upper part of the oral cavity only, with the pharynx not visible.

194 Quilis, A. and J. A. Fernández 1964

Curso de Fonética y Fonología Españolas: para estudiantes angloamericanos. Madrid: Consejo Superior de Investigaciones Científicas Instituto «Miguel de Cervantes».

Spanish 50fps

i,u,e,o,a,p,b,t,d,k,g,β,ð,s,x,ɣ,tʃ,l,r,ɾ 1

X*

spectrograms, palatograms

A course in Spanish phonetics and phonology for Anglo-American learners. X-ray tracings from a film taken at 50 fps are given of most Spanish segments (taken from connected speech). A few exemplary spectrograms (of the vowels) and palatograms (of the alveolar and palatal laterals as well as the palatal approximant) are also provided.

195 Retord, G. 1972

l'Agni, variété dialectale sanvi: phonologie, analyses tomographiques, documents. Annales de l'Université d'Abidjan - série H-V-fascicule 1.

Agni (Sanvi) still

i,ɩ,e,ɛ,ɑ,ɔ,o,ɷ,u,ĩ,ɩ̃,ɑ̃,ɷ̃,ũ,j,w,ɥ,p,b,t,d,c,ɟ,k,g,k͡p,g͡b,m,n,ɲ,ŋ,l,f,s,z 1

X*

articulatory measures

A study of the phonetics and phonology of the Sanvi dialect of Agni, spoken on the Ivory Coast. Lateral tomographs were taken of each segment and are reproduced photographically, along with the corresponding tracings. Some articulatory measures are also given.

196 Rochette, C.-E. 1973

Les groupes de consonnes en français: l'étude de l'enchaînement articulatoire à l'aide de la radiocinématographie et de l'oscillographie. Bibliothèque française et romane, Série A 23/I. Paris: Klincksieck.

French 48fps

p,b,m,f,v,t,d,n,s,z,k,g,ŋ,ʃ,ʒ,ɲ,l,ʁ 2

X*

oscillograms

A thorough study of consonant to consonant transition in French, showing frame by frame movements in every possible consonant cluster, taken from real word phrases.

197 Romportl, M. 1953

Fonetická studie o ruském «bl». Slavia 22:529-556.

Russian still

ɨ,i,u 2

X

palatograms, tables of acoustic measurements, spectra

A discussion of the Russian vowel usually symbolized as a "barred i" and its articulatory and acoustic properties. Comparisons are made with /i/ and /u/. Tracings are given of two speakers' pronunciations of the three vowels.

198 Rosetti, A. 1935

Contributions à l'analyse physiologique et à l'histoire des voyelles roumaines â et î. Bulletin Linguistique 3:85-112.

Rumanian still

ă,e,i,î,u 4

X*

articulatory measurements

Articulatory description of the Rumanian vowels â and î and a discussion of their historical development. A table of some articulatory measurements is included.

199 Rosetti, A. 1936

Sur le passage de Lat. et Sl. méridional o inaccentué à A en roumain. Bulletin Linguistique 4:52-63.

Rumanian — still

ă, o — 2

X*

articulatory measurements

Describes the historical sound change o>å on an articulatory basis from x-rays of these two vowels in contemporary Rumanian. Some articulatory measurements are given.

200 Russell, G.O. 1928

The Vowel. Columbus: The Ohio State University Press.

English (Am.) — still

i,ɩ,e,ɛ,æ,a,ɑ,ɔ,o,u,ə,y,ø,oa — 3

X*

photographs of the larynx, palatograms, cavity diameter measurements

X-ray tracings of German (from Barth and Grunmach 1907), French and American English vowels are given along with numerous palatograms and tables of cavity diameter measurements and some photographs of the larynx during phonation.

201 Russell, G.O. 1929-30

The mechanism of speech. Journal of the Acoustical Society of America 1: 83-109.

English (Am.), German, Spanish — still

i,ɩ,e,ɛ,æ,a,ɑ,ɔː,o,u,ω,ə,y,ʏ,ø,œ — plural

X*

Includes some of the tracings from his books (Russell 1928, 1931) from American English, North German and Spanish.

202 Russell, G.O. 1931

Speech and Voice. New York: Macmillan Co.

English (Am., Br.), French, German, Italian, Spanish — still
i,ɩ,e,ɛ,æ,a,ɑ,ɔ,o,ω,u,ə,y,ʏ,ø,uo,ue — plural
X*

photographs of the vocal cords

X-ray photographs and tracings are shown of some English, French, Spanish, Italian and German vowels. Vowels are also shown sung by a soprano, a tenor and a baritone. A few photographs of the larynx taken during vowel phonation are also given. A great deal of the data here duplicates his earlier book (Russell 1928).

203 Russell, G.O. 1933

First preliminary x-ray consonant study. Journal of the Acoustical Society of America 5: 247-251.

English — still
z — 1
X*

Comparison of the articulation of English /z/ in three vowel environments.

204 Russell, G.O. 1936

Synchronized x-ray, oscillograph, sound and movie experiments, showing the fallacy of vowel triangle and open-closed theories. Proceedings of the 2nd International Congress of Phonetic Sciences. London, 1935. Cambridge. Pp. 198-204.

X*

205	Santerre, L. 1971 La délimitation d'un continu phonétique. Travaux de l'Institut de Phonétique de Strasbourg 3: 185-195. French — fps l,u,p,aı,ɛ — ? L spectrograms Discusses the difficulty of dividing an utterance into discrete segments. To support his claim he gives examples from synchronized x-ray films (48 frames/sec) and acoustic recordings. Gvien are tracings of three superimposed frames from the word [lup] which begin at a point just after the release of the [l] and end at the [p] closure. I The subject is a French speaker, but the dialect is not specified. Two other composite tracings are provided from a working class speaker of Montreal French. Each composite tracing is accompanied by a synchronous spectrogram with the moments for each frame indicated. Also given are various articulatory measurements over time.	
206	Santerre, L. 1972a Corrélations entre les mouvements articulatoires et les variations formantiques. In A. Rigault and R. Charbonneau (eds.), Proceedings of the Seventh International Congress Of Phonetic Sciences, Montréal, pp. 389-400. The Hague: Mouton. French(Montreal) — ? ə,ɛ,e,i,ɔ,o,u,a,ɑ — ? X formant frequencies Seeks to establish correlations between variations in formant frequencies and variations in cavity shape with the use of x-rays and synchronized spectrograms. The x-rays given are only a portion of those in his book (Santerre 1972b) and are taken from real word sentences.	
207	Santerre, L. 1972b Les Voyelles Orales dans le Français Parlé à Montréal. Paris: Klincksieck.(Unsure if this book ever actually came out, since it doesn't appear in the Klincksieck catalogue).	

208 Scatton, E.A. 1984

A Reference Grammar of Modern Bulgarian. Columbus, OH: Slavica.

Bulgarian ?

i,e,a,o,u,ʉ,p,pj,t,tj,s,sj,l,lj,ʃ ?

X*

The phonology section of this grammar includes tracings from Stojkov (1966).

209 Simon, P. 1961

Films radiologiques des articulations et les aspects génétiques des sons du langage. Orbis 10: 47-68.

French 50,64fps

2

X

Gives a historic development and bibliography of x-ray studies up to that time. In addition, the author discusses some preliminary results of her own cineradiographic studies, particularly for the French language. No tracings are included.

210 Simon, P. 1967

Les consonnes françaises (mouvements et positions articulatoires à la lumière de la radiocinématographie). Bibliothèque française et romane, Série A, No. 14. Paris: Klincksieck.

French 24fps

p,b,m,f,v,t,d,n,s,z,ʃ,ʒ,l,ɲ,j,ɥ,k,g,w,ʁ,a,i,ø,o,œ̃,ɑ̃,e,õ 1

X

articulatory measurements

A thorough x-ray study of French consonants (some vowels are also included). 162 tracings are given, each one a composite of several successive frames of the segment in question. Each segment is shown in a variety of phonetic environments and a number of articulatory measurements taken from the x-rays are provided. Also included is a bibliograpohy of x-ray studies up to that time.

211 Simon, P. 1970

A propos de la désarticulation de la consonne palatale n dans la prononciation du français d'aujourd'hui. In Phonétique et Linguistique Romanes: Mélanges offerts à M. Georges Straka, Lyon-Strasbourg, Vol. 1.

French — 50fps

ɲ,nj,n — 1

O,X

spectrograms

Tracings are given comparing successive cine-x-ray frames of palatal n, alveodental n and n+j sequences in contemporary French. Some spectrograms from a simultaneous acoustic recording are also included.

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212 Simon, P. and A. Bothorel 1980

Les mouvements labiaux et leurs rapports avec les autres structures articulatoires en chaîne parlée. Paper given at G.A.L.F.: Groupe de la Communication Parlée. International Seminar on Labiality 7-8 February, 1980. Centre National d'Etudes des Télécommunications, Lannion, France.

Breton, French, Icelandic, Korean — still/fps

plural

X

The authors discuss the correlation between lip protrusion and other articulatory parameters (lip opening, lower jaw position, position of the tongue, displacement of the hyoid bone/larynx) using as their database of mainly cine-x-rays of Breton (Bothorel 1982), French (Brichler-Labaeye 1970, Simon 1967), Icelandic (Pétursson 1974b) and Korean (Han 1978). No tracings are included, but all the discussion results from comparison of x-ray data.

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213 Simon, P., G. Brock and M-H. Han 1977

Description et utilisation d'un equipement à rayons X pour l'étude de certains aspects articulatoires: application au coréen. In R. Carre, R. Descout, M. Waiskop (eds.) Modèles Articulatoires et Phonétique. G.A.L.F. Groupe de la Communication Parlée. (Grenoble, July 10-12, 1977).

Korean — 64fps

p,ph,p*,t,th,t*,k,kh,k*,a,ɛ,o,ɯ — 1

X

spectrograms, tables of articulatory measurements

An x-ray study of the three-way consonant distinction in Korean. Articulatory measurements are compared to clarify the difference between the three phonemes. 15 tracings are given illustrating the three consonat types in all three places of articulation and in different vowel contexts. The fortis stops are symbolized here with an asterisk.

214	Simon, Péla, François Wollf, Hossein Nadjafizadeth & Gilbert Brock 1984 Numérotation automatique et codage synchrone graphique et phonique pour l'exploitation des films radiologiques. Travaux de l'Institut de Phonétique de Strasbourg No.16: 181-190. French — 50fps u,i,s,ʒ — 1 L Describes in detail the apparatus used at the University of Strasbourg for making cine-x-rays with synchronous acoustic recordings (or, for medical purposes, simultaneous coronarographs and electrocardiograms. Examples are given of a few French segments.
215	Skaličková, A. 1955 The Korean vowels. Archivu Orientálni 23: 29-51. Korean
216	Skaličková, A. 1960 The Korean Consonants. Prague: Rozpray CSAV. Korean

217 Skaličková, A. 1967

A radiographic study of English and Czech vowels. Phonetica Pragensia 1: 29-44.

English (Br.), Czech — still/fps

i,ɪ,e,a,æ,ʌ,ɑ,o,ɔ,u,ʊ,ə — 1

O,X*

formant frequencies

A comparison of English and Czech vowels.

218 Skaličková, A. 1974

Srovnávací fonetika angličtiny a češtiny. Praha: Academia.

Czech, English — still/fps

í,i,ɪ,e,é,a,á,æ,ʌ,ə,ɑ,ɔ,o,ó,u,ú,ʊ,p,t,d,k,c,ɟ,tʃ,ts,dz,θ,ð,f,s,ʃ,j,x,m,n,ɲ,ŋ,l,r — plural

ř,ɹ,w — X*

labiograms, waveforms

A comparison of English and Czech sounds. The tracings are stylized, but taken from genuine x-rays, both still and cine. Included are frontal and lateral labiograms of English and Czech vowels and some waveforms.

219 Skalidis-Konstantinidis, R. M. 1980

l'Accent dans la langue turque parlée à Istanbul. Travaux de l'Institut de Phonétique de Strasbourg No. 12: 159-175.

Turkish — 50fps

p,d,g — 1

L

graphs of Fø and intensity

A discussion of word accent in Turkish.

220 Skalidis-Konstantinidis, R.M. 1981

Les occlusives du turc parlé à Istambul: étude radiocinématographique, oscillographique et sonagraphique. Travaux de l'Institut de Phonétique de Strasbourg 13.

Turkish 50fps

p,b,m,t,d,n,k,g,i,a 1

L

spectrograms, laryngeal, oral and nasal audio, oral airflow

A study of the occlusives of Istanbul Turkish. Tracings are given of each segment in many different environments and differents points in time. Also included are spectrograms of the utterances and oscillomink traces of the laryngeal, oral and nasal audio signal as well as oral airflow.

221 Skalozub, L.G. 1957

Sopostavitel' noe opisanie soglasnykh sovremennykh koreiskogo i russkogo iazykov. Kiev. I Univ. Laboratoria Eksperimental noi fonetiki. Raboty.

222 Skalozub, L.G. 1963

Palatogrammy i Rentgenogrammy Soglasnyx Fonem Russkogo Literaturnogo Jazyka. Kiev: Izdatel'stvo Kievskogo Universiteta.

223 Skalozub, L.G. 1966

Uprazhneniia Po Fonetike Russkogo Iazyka. Kiev University, Laboratory of Experimental Phonetics.

Russian still

i,ɨ,ɛ,ɔ,u,a,j,p,pj,b,bj,m,mj,f,v,t,tj,d,dj,n,nj,s,sj,z,š,ž,ts,č,ɫ,lj,r,rj,k,kj,g ?

x,xj X*

palatograms, some labiograms

Most Russian segments shown in different environments in tracings as well as palatograms. Labiograms (both frontal and lateral) are given for a few segments.

224 Smith, T. 1971

A phonetic study of the function of the extrinsic tongue muscles. UCLA Working Papers in Phonetics 18.

English(Am.) 24fps

i,e,a,t,d,k 1

W,O

EMG records of extrinsic tongue muscles, spectrograms, graphs of articulatory measures

In this EMG study of the extrinsic tongue muscles is also included an x-ray study of one subject. There are no tracings included, however. Data is presented in the form of graphs of articulatory movements (position of hyoid bone and width of pharynx).

225 Sonninen, A. 1962

Paratasis-gram of the vocal folds and the dimensions of the voice. Proceedings of the 4th International Congress of Phonetic Sciences, Helsinki, 1961, pp. 250-258. The Hague: Mouton.

X*

226 Sovijärvi, A. 19**

Die wechselnden und festen Formanten der Vocale, erklärt durch Spektrogramme und Röntgenogramme der finnischen Vokale. Proceedings of the Third International Congress of Phonetic Sciences, Gent. Pp. 407-420.

Finnish

227 Sovijärvi, A. 1959

Uber die Veränderlichkeit der Zungenstellung und der entsprechenden akustischen Schwankungsgebiete der Vokale auf Grund eines Röntgentonfilms gesprochener finnischer Sätze. Phonetica 4, Supplement, (Symposion Trubetzkoy) 74-84.

Finnish

X*

228 Sovijärvi, A. 1962

Röentgenkinematografisch-akustische Untersuchungen über die Artikulation der Diphthonge. Proceedings of the 4th International Congress of Phonetic Sciences, Helsinki, 1961. The Hague: Mouton. Pp. 111-128.

Finnish 48fps

ai, æi, ei, au, iu, ie 1

X

wide band spectrograms with intensity traces, spectra

Discusses 6 out of the 18 Finnish diphthongs. Composite tracings showing the movement from one component to the other are given for each diphthong as well as spectra taken at successive movements in the vowels and wide band spectrograms with intensity tracings. The subject was a ten year old boy from Helsinki.

229	Sovijärvi, A. 1963 Suomen Kielen Äännekuvasto. Jyväskylässä: K.J. Gummerus Osakeyhtiö. Finnish — still? y,ø,u,o,i,e,ɛ,a,p,b,m,f,v,t,d,n,l,s,r,ʃ,j,k,g,ŋ,h — 1 X* labiograms (lateral and frontal), palatograms Stylized x-ray tracings, labiograms and a few palatograms are given of many of the sounds in Finnish. Some consonants are shown in different vowel environments. The book also contains a phonograph record illustrating the sounds discussed.
230	Sovijärvi, A. 1969 Der Lautübergang im Lichte von Röntgenfilmen und Spektrogrammen. Annales Academiae Scientiarum Fennicae. Ser. B. Vol. 153.3. Helsinki: Suomalainen Tiedeakatemia. Finnish — fps ä,äy,p,t,s,sk,r — 2 X* formant frequencies Compares dental and labial effects on tongue position for the vowel /ä/ by the use of x-ray cinematography. The figures are not tracings of x-rays, but are photographs of A.D.A.M. (Apparatus for Demonstrating Articulatory Movements) which has been adjusted to simulate the x-rays.
231	Sovijärvi, A. 1972 New observations of certain CV and VC transitions. In A. Rigault and R. Charbonneau (Eds.) Proceedings of the Seventh International Congress of Phonetic Sciences, Montréal. The Hague: Mouton. Finnish — fps i,h

232	Stevens, K.N. and J.S. Perkell 1977 Speech physiology and phonetic features. In M. Sawashima and F.S. Cooper (eds.) Dynamic Aspects of Speech Production. Tokyo: University of Tokyo Press:323-345.
233	Stojkov, S. 1942 Bulgarski Knizhoven Izgovor: Opitno Izsledovanie (Bulgarian Literary Pronunciation: Preliminary Investigations). Sbornik na Bulgarskata Akademija na Naukite u Izkustvata, Vol. 37: 3. Durzhavna Pechatnitsa. Bulgarian i,e,a,o,u,ʉ,j,m,f,t,tj,n,nj,ts,s,tʃ,ʃ,k,kj,x,r,rj,l,lj X* palatograms, linguagrams, lip position and pitch measurements A study of Bulgarian literary pronunciation with x-ray tracings, palatograms and linguagrams from a number of subjects and some measurements of lip position and pitch curves.
234	Stojkov, S. 1961 Uvod v Bulgarskata Fonetika (Survey of Bulgarian Phonetics). 2nd revised edition. Sofia: Nauka i Izkustvo. Bulgarian ? i,ɨ,e,a,o,u,p,pj,m,mj,t,tj,n,nj,k,kj,f,fj,s,sj,š,x,xj,ts,tsj,tʃ,l,lj,r,rj ? palatograms, linguagrams, kymograms, labiograms Contains palatograms, linguagrams, kymograms, and labiograms in addition to the x-ray tracings. All Bulgarian speech sounds are covered.

235 Stojkov, S. 1966

Uvod vuv Fonetikata na Bulgarskija Ezik. Sofia: NI.

236 Stojkov, S. 1967

Banatskijat Govor. Sofia: Bulgarska Akademija na Naukite.

Bulgarian (Banat) ?

i,ɨ,e,ɛ,ə 1

X*

formant frequencies, spectrograms, palatograms, linguagrams

Describes the Bulgarian dialects spoken in the Banat.

237 Straka, G. 1942

Notes sur la vocalisation de l'l. Bulletin Linguistique 10:5-34.

Czech, Russian still

l 2

X*

palatograms

A discussion of the vocalisation of /l/ and the aticulation of non-vocalized /l/ in numerous languages. 3 x-ray tracings are given, two of Russian and one of Czech (from Polland and Hála 1926). These are supplemented by palatograms of /l/ in various languages.

238 Straka, G. 1963

La division des sons du langage en voyelles et consonnes peut-elle être justifiée? Travaux de Linguistique et de Littérature. Strasbourg: Le Centre de Philologie et de Littératures Romanes 1: 17-99.

French — still, 50fps

a,i,e,t — plural

X*

labiograms, spectrograms, palatograms

16 tracings, some composite, are included in this paper, showing differences between segments uttered normally and the same segments uttered more energetically. The tracings are from several sources, mostly from the University of Strasbourg collection and also from Chlumsky. Some are still x-rays, others are from cine-x-ray films. Labiograms taken from a cine-film of the lips, palatograms and a few spectrograms are also included.

239 Straka, G. 1964

L'évolution phonétique du latin au français sous l'effet de l'énergie et de la faiblesse articulatoires. Travaux de Linguistique et de Littérature. Strasbourg: Centre de Philologie et de Littératures Romanes. 2:1 pp.17-98.

Alsacian, French, German, Russian, Spanish — still/fps

i,ɨ,e,ɛ,a,ɑ,o,ɔ,u,y,ø,œ,ɛ̃,œ̃,ɑ̃,õ,w,β,dj — plural

X*

palatograms, laryngeal and nasal audio traces, oral airflow traces

Tracings taken from various sources as well as original radiofilms are given for French, German, Alsacian, Russian and Spanish, mostly illustrating differences in force of articulation. Palatograms and reproductions of laryngeal and nasal audio and oral airflow tracings are also given.

240 Straka, G. 1965a

Album Phonétique. Québec: l'Université Laval.

Czech, English, French, German, Russian, Spanish — .

i,e,ɛ,a,ə,o,ɔ,u,y,œ,ɑ̃,õ,œ̃,ɛ̃,j,ɥ,w,p,b,m,t,d,n,tj,kj,k,g,s,z,ʃ,ʒ,f,v,ɸ,β,l,ʎ,ɫ,l — 1?

j,pj,ɨ,i,u,ts,tʃ — L

palatograms, spectrograms, kymograms, oscillograms

This is in textbook form and thus particular tracings are not always easy to locate, but all examples are supposed to be from real x-rays. Most of the tracings are of French, but examples are also given from English, Spanish, Russian, Czech and German. Also to be found are palatograms, spectrograms, kymograms and oscillograms.

241 Straka, G. 1965b

Naissance et disparition des consonnes palatales dans l'évolution du latin au français. Travaux de Linguistique et de Littérature. Strasbourg: Centre de Philologie et de Littératures Romanes 3:1 pp.117-167.

Czech,French — still/fps

ƫ,tj̡,dj̡,ᶄ,ᶅ,ʎ̡,i — plural

X*

palatograms, laryngeal and nasal audio tracings, oral airflow tracings

Tracings of French and Czech palatalized segments are given. The Czech tracings are from Hála. Also shown are palatograms from several languages and traces of laryngeal and nasal audio and oral airflow recordings.

242 Straka, G. 1965c

Contribution à l'histoire de la consonne R en français. Neuphilologische Mitteilungen 46:4 pp.572-606.

French — fps?

r̡,ʀ̡,ʁ̡,ᶅ,ᶎ,ð — plural

X*

palatograms

The different variants of /r/ in the history of the French language are illustrated by x-rays and palatograms from various contemporary French dialects (meridionale, Puy-de-Dôme, Parisienne).

243 Strenger, F. 1956

Cephalometric x-ray analysis of the position of the mandible in the pronunciation of Swedish vowels. Odontologisk Revy 7.1: 103-117.

Swedish

244 Strenger, F. 1963

Untersuchung Schwedischer Konsonanten nach der indirekten Palatogramm-Methode. Zeitschrift für Phonetik 16: 211-216.

Swedish — still

d,s,k,ŋ,v — 1

X

linguagrams

Photographs of x-rays (not very easy to read) are given for Swedish /d,s,k,v/ and the velar nasal. In addition, there are linguagrams of Swedish /f,v,t,d,l,n,s,k,g/ and the velar nasal.

245 Strenger, F. 1968

Radiographic, palatographic, and labiographic methods in phonetics. In B. Malmberg (ed.), Manual of Phonetics. Amsterdam. Pp. 334-364.

Swedish — still

iː,yː,uː,m,n,ŋ,f,d — 3

X

labiograms, palatograms, linguagrams

Describes the experimental techniques of radiography, palatography and labiography. X-ray photographs are shown of a subject with normal dentition (rest,i:,y:,m,n,N,f,), a subject with mandibular protrusion and open bite (rest, u:,m,n,N,f) and a subject with no teeth (f,d). A few palatograms, linguagrams and labiograms are also provided.

246 Strenger, F. 1969

Les Voyelles Nasales Françaises. Travaux de L'Institut de Phonétique de Lund. Lund: Gleerup.

French — still

ɛ,ɛ̃,e,œː,œ̃,ø,ɔː,ɔ̃,oː,ɑ,ɑ̃,a,m,n,ɲ — 1

X*

labiograms, articulatory measures

Compares French nasal vowels and their oral counterparts as well as nasal consonants, using cephalometric radiography and frontal labiograms. The photographs of x-rays are sometimes difficult to read. Some articulatory measures are given in a table at the end of the book.

247 Styczek, I. 1973

Badania Eksperymentalne Spirantów Polskich s,š,ś ze Stanowiska Fizjologii i Patologii Mowy. Warsaw: Polska Akademia Nauk.

Polish — still

s̪,ʂ,ɕ — 46

X*

palatograms, linguagrams, labiograms

A study of three voiceless fricative phonemes in Polish. 13 normal subjects are illustrated with x-ray tracings, palatograms, linguagrams and, for one subject, labiograms. 33 pathological cases are also shown.

248 Subtelny, J.D. and J. Subtelny 1962

Roentgenographic techniques and phonetic research. Proceedings of the 4th International Congress of Phonetic Sciences, Helsinki, 1961. The Hague: Mouton. Pp. 129-146.

English(Am.)

s,u,a

X*

Includes cephalometric x-ray and laminagraph photographs and the corresponding tracings.

249 Subtelny, J.D., J.C. Mestre, and J.D. Subtelny 1964

Comparative study of normal and defective articulation of /s/ related to malocclusion and deglutition. Journal of Speech Disorders 29: 269-285.

English(Am.) — still

s — 81

X*

articulatory measures

Compares the articulation of /s/ in normal speakers and in those with defective oral anatomy (the latter group divided into those whose articulation of /s/ was affected by the abnormality and those who nevertheless articulated normally). Tracings are given of several speakers.

250 Subtelny, J.D., N. Oya, and J. Subtelny 1972

Cineradiographic study of sibilants. Folia Phoniatrica 24: 30-50. Basel: S. Karger.

English(Am.) 240fps

s,z,i,ɪ,æ,ɔ,u 10

X*

tables and graphs over time of articulatory measurements

A study of normal sibilant articulation and coarticulation. Tracings are given of several subjects.

251 Subtelny, J.D., S. Pruzansky, and J. Subtelny 1957

The application of roentgenography in the study of speech. In L. Kaiser (ed.), Manual of Phonetics. Amsterdam: No. Holland Publishing. Pp. 166-179.

English(Am.) still

a,ã,u 3

X*

A description and history of different x-ray methods used in speech research. Included are laminagraph tracings of 2 normal subjects uttering the vowel /a/ one nasally, the other non-nasally and an x-ray photograph of the /u/ of a speaker with an abnormal palate.

252 Sundberg, J. 1969

Articulatory differences between spoken and sung vowels in singers. Stockholm RIT STLQPSR 1: 33-46. [**Referred to in annotation as "Sundberg 1969-70"]

Swedish

u,o,ɑ,æ,e,i,y,ʉ,ø 1

X*

Examination of the articulatory differences between spoken and sung vowels. One composite x-ray tracing is shown of the Swedish vowel [u], both as spoken and as sung by one speaker. In addition, plots of larynx position, depression of the mandible and lip opening are given for 9 Swedish vowels.

253 Suntsova, I.P. 1960

Vstupnij Kurs Fonetiki Nimec'koe Movi. Kiev: "Radjans'ka Skola".

254 Švarný, O. and K. Zvelebil 1955

Some remarks on the articulation of the "cerebral" consonants in Indian languages, especially in Tamil. Archiv Orientalni 23: 374-434.

Tamil,Telugu, Urdu — still

ʈ,ʈ̪,ʈ̣,ɖ,ɖ̣,ɳ,ɳ̣,ɭ,ɭ̣,s,ṣ,tʃ,*,r,ṛ*,ç,c,ɟ — ?

X

palatograms, linguagrams

Compares segments from Tamil, Telugu and Urdu. In addition to the x-rays there are palatograms showing the segments in several different environments and a few linguagrams. The x-rays are given as both photographs and tracings.

255 Takenuchi, Y. 1961

Perceptual segmented Japanese monosyllables. In Hisanosuke Izui (ed.), Studia Phonologica. University of Kyoto, Japan. Pp. 70-85.

Japanese — still

i,e,a,o,u — 1

X*

table of articulatory measurements

X-ray photographs (rather hard to read) are reproduced here for the 5 Japanese vowels and for each of these vowel tongue positions combined with the jaw position of one of the other vowels.

256	Tambovtsev, Y. 1980 The application of x-ray method to the study of Mansi vowels. Bulletin of the Phonetic Society of Japan 164:13-16. Mansi iː,ɛː,aː,oː,uː X Articulatory classification of 5 Mansi vowels. No tracings are shown. Most of the article discusses the proper method for taking and analyzing x-ray photographs.
257	Tarneaud, J. and S. Borel-Maisonny 1941 Traité Pratique de Phonologie et de Phoniatrie. Paris:Librairie Maloine. French still i,e,a,o,u,y,œ,ã,õ,p,t,k 1 X* This extensive treatise on the voice, while largely concerned with singing and with speech therapy, also includes a section on normal speech in which are to be found several x-ray tracings. In an earlier section there are also some tomographs of the larynx (frontal view) during 4 sung vowels.
258	Ten Cate Kazejewa, B. 1929 Analyse phonétique du son «bl» de la langue Russe: Note préliminaire. Archives Néerlandaises de Phonétique Experimentale 4:47-59. Russian still i,ɨ,u 3 X* traces of various articulatory movements An early x-ray study of the Russian high central vowel comparing it to /i/ and /u/. X-ray photographs are reproduced of each of the three vowels for one speaker. In addition, there are a number of traces taken from early experimental techniques showing (grossly) oral airflow, height of larynx, forward and backward position of the larynx and jaw, upper lip and oral cavity wall movement.

259	Tilkov, D.	1970

Le Vocalisme Bulgare (La Société de Linguistique de Paris, Collection Linguistique No. 65). Paris: Klincksieck.

Bulgarian — 50fps
a,ə,o,u,e,i,p,b,m,t,d,k,g,tʃ,l,v,f,s,h — 1
L

tables of measurements and formant values, palatograms, spectrograms, amplitude displays

An articulatory and acoustic study of Bulgarian vowels with data on vowels in various stress and consonant environments. Frame by frame tracings of whole phrases are given which, as well as the vowels, necessarily include a number of Bulgarian consonants as well. A few palatograms are given of the vowels, as well as spectrograms and amplitude displays of the test utterances.

260	Tots'ka, N.I.	1966

Vpravi z Fonetiki Sučasns'noj Literaturnoj Movi. Kiev: Redactor dots I.P. Suntsova.

Ukrainian
i,ɨ,e,a,o,u,t,tj,n,nj,s,sj,ʃ,k,kj
X*

palatograms

An exercise book for students with tracings of some of the sounds of Ukrainian and a few palatograms. A number of tracings are left unlabeled as an exercise for the students.

261	Tots'ka, N.I.	1973

Golosni Fonemi: Ukrainsvkoi Literaturnoi Movi. Kiev: Vidavnitstvo Kievs'kogo Universitety.

Ukrainian — 50fps
a,o,u,e,i,ɨ — 3
X*

palatograms, formant frequencies

Included are x-ray tracings, palatograms and formant frequencies of Ukrainian vowels, with several successive frames from the same utterance..

262 Traill, A. 1985

Phonetic and Phonological Studies of !Xóõ Bushman. Hamburg: Helmut Buske Verlag.

!Xóõ — still/fps

i,e,ɑ,o,u,ɜ,ʉ,ɑ̱,ʉ̱,ɑ̱h,ʉ̱h,ʘ,ǂ,ǀ,ǁ,ǃ,ǂq,n̤ǂ — 5

L

pressure and flow records, laryngographic records, fiberoptic views of larynx, spectrograms, palatograms

A thorough study of !Xó~o Bushman including some x-rays tracings of vowels and click consonants. Some were from still x-rays, others were filmed at 25 and 50 fps. In addition, numerous other kinds of instrumental data are provided, including oral and pharyngeal air pressure, nasal and oral airflow, laryngographic data, fiberoptic views of the larynx, spectrograms and palatograms.

263 Truby, H.M. 1962

Synchronized cineradiography and visual-acoustic analysis. Proceedings of the 4th International Congress of Phonetic Sciences, Helsinki, 1961. The Hague: Mouton. Pp. 265-279.

English (Am.) — 48fps

a,u,l — 1

O,X*

spectrograms

Includes x-ray photographs of /a/, /u/ and /l/ in real words with initial Cl clusters.

264 Van Dantzig, B. 1929

Der Einflusz des hetero-syllabischen Jots auf einige vorangehende Vokale in der niederlaendischen Sprache. Archives Néerlandaises de Phonétique Expérimentale 4:60-66.

Dutch — still

o — 2

X*

palatograms

An investigation of the influence of a following palatal consonant (after the addition of the diminutive /je/) on vowel quality in Dutch. X-ray photographs (rather hard to decipher in reproduction) are shown of one speaker's production of the vowels in "mond" and "mondje". There are also palatograms from two subjects.

265 Wada, T., M. Yasumoto, N. Ikeolea, Y. Fiyuki, & R. Yoshinaga 1970

An approach for the cinefluorographic study of articulatory movements. Cleft Palate Journal 7: 502-522.

266 Wängler, H-H. 1958

Atlas deutscher Sprachlaute. Berlin: Akademie-Verlag.

German — still

p,t,k,m,n,ŋ,f,s,ʃ,ç,x,l,r,ʀ,a,ɑ,ɛ,e,ə,ɩ,i,ɔ,o,ɷ,u,œ,ø,y,ʏ — 1

X*,L

labiograms (front and side), palatograms

A documentation of the sounds of German giving, for each segment, an x-ray photograph, front and side labiograms and a palatograms. Overlay tracings are provided for clarity.

267 Wängler, H-H. 1974

Grundriss einer Phonetik des Deutschen, 3rd ed. Marburg: N.G. Elwert.

German — still

iː,ɩ,yː,ʏ,eː,ɛ,øː,œ,ə,ɑː,a,oː,ɔ,uː,ɷ,aɔ,aɩ,ɔɩ,b,d,g,m,n,ŋ,v,z,ʃ,j,x,l,r,ʀ — 1

X*

formant frequencies, spectrograms and fundamental frequency contours

A textbook of basic phonetics, applied to the description of German. Tracings, which appear to be the same as those in Wängler 1958, are given of most German segments. There is also discussion of German intonation.

268	Warnant, L.	1953

Etudes Phonétiques sur le Parler Wallon d'Oreye. Liège: Michiels.

269	Warnant, L.	1956

La Constitution Phonique du mot Wallon. Paris: Societé d'édition "Les Belles Lettres" (Bibliothèque de la Faculté de Philosophie et Lettres de l'"Université de Liège 135).

Wallon	still
p,b,m,f,v,t,d,n,s,z,ʃ,ʒ,tʃ,dʒ,ɲ,k,g,l,r,h,j,w,i,e,ɛ,a,ɑ,ɔ,o,u,y,ø,œ,ɛ̃,ã	1
	X*

palatograms, labiograms

A description of the phonetics and phonology of the Wallon spoken in Oreye in the Hesbaye Liegeoise region. Tracings of still x-rays as well as palatograms and labiograms from the same speaker are given for each segment. Many consonants are shown in a variety of vowel environments.

270	Weinberg, B.	1968

A cephalometric study of normal and defective /s/ articulation and variations in incisor dentition. Journal of Speech Research 11: 288-300.

English (Am.)	still
s	39
	X*

tables of statistical analyses of articulatory measures

A comparison of the articulation of /s/ in 13 normal children, 13 children with missing central incisors but normal /s/ articulation and 13 children with missing upper central incisors and defective /s/ production. A number of measurements were taken from the cephalometric films and statistical analyses performed on them The results are given in tables. Tracings of /s/ production in 4 speakers are shown.

271 Wierzchowska, B. 1967

Opis Fonetyczny Jezyka Polskiego. Warsaw: Panstwowe Wydawnictwo Naukowe.

Polish — still,fps

i,ɨ,e,a,o,u,j,w,ĩ,ɨ̃,ẽ,ã,õ,ũ,j̃,p,b,m,f,t,d,n,s̪,z̪,ts,t,tṣ,dẓ,ṣ,ẓ,k,ŋ,x,l,ɫ,r,pj,bj, — plural

fj,vj,mj,dj,tsj,dzj,nj,ṣj,tṣj,gj,ŋj,xj,lj,rj — X*

palatograms, linguagrams, labiograms, spectrograms

A study of most of the speech sounds of Polish using still x-rays as well as, for some segments, cine-x-rays. Tracings are supplemented by occasional palatograms, linguagrams, labiograms and spectrograms. Allophonic variation in vowels is shown.

272 Wierzchowska, B. 1980

Fonetyka I Fonologia Jezyka Polskiego. Warsaw: Ossolineum

Polish — still,fps

i,ɨ,e,a,o,u,j,w,õ,ẽ,j̃,p,b,m,bj,mj,t,d,n,dj,nj,k,ŋ,kj,f,fj,s̪,zj,ṣ,ts,tsj,ɕ,x,xj, — plural

l,ɫ,lj,r,rj — X*

labiograms, linguagrams, palatograms, spectrograms

A study of Polish phonetics and phonology with most Polish sounds illustrated by x-ray tracings, labiograms, linguagrams, palatograms and spectrograms. Much, but not all, of the data is from Wierzchowska 1967.

273 Wood, S. 1975

What is the difference between English and Swedish dental stops. Working Papers, Phonetics Lab. Lund University, 10: 173-193.

English (Br.), Swedish — 75fps

ɛ,ɑ,o,t̪,d,n — 2

X*

area functions, spectrograms, spectra

Compares an English speaker's laminal alveolar with a Swedish speaker's apical alveolar stops and looks at them from several different angles: x-ray tracings, area functions, spectrograms and burst spectra.

274 Wood, S. 1979

A radiographic analysis of constriction location for vowels. Journal of Phonetics 7: 25-43. Also in Working Papers, Lund University, No.15 (1977).

Arabic (Cairo), English (Br.), Eskimo (West Greenlandic) | 75fps
i,ɪ,e,ɛ,æ,a,ɑ,ə,ɔ,o,ʊ,u | 3
L

area and resonance sensitivity functions, formant frequencies

Includes tracings of vowels in British English, Cairo Arabic and West Greenlandic Eskimo. Also provided are vocal tract area and resonance sensitivity functions and formant frequencies.

275 Wood, S. 1982

X-ray and model studies of vowel articulation. Working Papers, Phonetics Lab, Lund University, 23.

Arabic (Cairo), English (Br.), Eskimo (West Greenlandic) | 75fps
i,ɪ,ɛ,ɑ,o,ʊ,u,p,b | 3
L

area functions, formant frequencies, spectrograms

A collection of 5 papers involving x-ray and model studies. Tracings are given of a number of languages from sources in the literature (reviewed in this bibliography) as well as 3 original films at 75fps of British English, Cairo Arabic and Greenland Eskimo. Nearly all of the tracings are of vowels. In addition, graphs of area functions, formant frequencies and a few spectrograms are given,

276 Zawadski, P.A. 1981

Tongue apex activities during alveolar stops. Phonetica 38:227-235.

English (Am.) | 100fps
t,d | 5
X*

graphs of articulatory measures

A study of tongue tip velocity in moving from various vowels toward and alveolar stop. Nonsense trisyllables of the form aCVCa were filmed at 100 fps with a tracking pellet affixed to the tongue apex. Data is presented in the form of only two figures, one a graph of tongue apex height as a function of time and the other a graph of tongue apex speed against distance travelled going from stressed or unstresses vowels toward the alveolar closure. No tracings are provided.

277 Zebek, H. 1962

Wymowa Francuska. Warsaw: "Wiedza Powszechna".

278 Zerling, J.-P. 1980

Corrélations entre variabilité articulatoire et variabilité acoustique chez deux locuteurs. XIèmes Journées d'Études sur la Parole du Grupe Communication Parlée. Strasbourg: Institut de Phonétique de l'Université.

French ?

g,a,ɔ 2

The author has made extensive measurements of x-ray films from two speakers of French, to determine inter and intra subject differences, documenting not only anatomical differences, but compensatory relationships between articulators. X-ray tracings given are of the consonant [g] in the vowel environments of [a] and [O] for two speakers.

279 Zerling, J.-P. 1984

Phénomènes de nasalité et de nasalization vocaliques: étude cinéradiographique pour deux locuteurs. Travaux de l'Institut de Phonétique de Strasbourg No.16: 241-266.

French fps

ɛ,ɛ̃,œ,œ̃,ɑ,ɑ̃,ɔ,ɔ̃ 2

L

graphs of articulatory measurements

An articulatory comparison between French oral vowels, nasal vowels and nasalized vowels (phonologically oral vowels between two nasal consonants).

280 Zhou and Wu 1963

Articulation Album of Putonghua.

Mandarin (Beijing)
i,e,a,o,u,ə,y,ʅ,ɿ,ai,ei,ao,ou,an,aŋ,b,p,m,f,d,t,n,l,g,k,ŋ,x,tɕ,tɕʰ,ɕ,tʂ,tʂʰ,
ʂ,ts,tsʰ,s,ɹ,ɻ

still
6
L,X

labiograms, palatograms

A description of the popular dialect of Mandarin spoken in Beijing. X-rays were taken of six subjects although tracings of only one representative subject are shown. Also given are fronatal and lateral labiograms and palatograms for each segment.

281 Zwaardemaker, H. 1915

Leerboek der Physiologie. Haarlem: De Erven F. Bohn.

Dutch
i,a,u,d,n,l

still
1
X*

Nasal airflow traces, palatograms, traces of velum, upper lip and jaw movement

This book on physiology contains some early phonetic exploration including x-ray tracings, palatograms, traces of velum, upper lip and jaw movement and nasal airflow traces.

282 Zwirner, E. 1936

Speech and speaking. In Daniel Jones and D.B. Fry (eds.), Proceedings of the 2nd International Congress of Phonetic Sciences. Cambridge. Pp. 239-245.

German
e

still
3
X*

waveforms

Notes the differences and similarities of three subjects' /e/ vowel sung on the same pitch.

Macintosh computer programs for phoneticians

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There are a number of commercial and other programs available for speech analysis and synthesis on Macintosh computers. Undoubtedly the most important of these is **SoundWave**, now published by Impulse Corporation. This is a new version of a program previously called SoundCap, which used to be published by the MacNifty Corporation. The current list price for the improved system is a little under $200, and it should be available for much less through the mail order discount suppliers. Using the default sample rate of 22,500 Hz, it is possible to store about 38 seconds of speech on a MacPlus, and about half that on a 512K machine. The system includes (at that price!) the hardware to digitize sound, as well as the necessary software . No filters are included, so, unless the user adds a filter, there will be aliasing from frequencies above 11,250 Hz; but we are seldom concerned with energy above this frequency. One can display and edit the waveforms using standard Macintosh techniques, such as using the mouse to select a length of the displayed waveform, and, then, with the menu or command keys, cut, copy, paste, or even mix it into other files in ways immediately familiar to anyone who has used a Macintosh for word processing. One possible limitation is that the samples are only 8 bits; but there is a very convenient oscilloscope mode that allows one to adjust the intensity of the incoming signal so that the full 8 bit resolution is used. As a result one can record a signal with a flat frequency response up to 10 kHz, and with a signal-to-noise ratio better than 40 dB, which is more than enough for most phonetic purposes.

The program as it is commercially available includes a spectral analysis option, but with no pre-emphasis, and unsuitable bandwidths, so that it is not very useful from our point of view. But it also includes provision for inserting custom routines into the menu, and a good description in the manual as to how to do this. We are currently writing a number of routines for phonetic purposes, all of which will be in the public domain. As it stands, the system provides by far the cheapest and best waveform editor on any microcomputer known to us; eventually it should be a good, cheap, basic system, capable of handling many of our phonetic needs.

We have developed within the UCLA Phonetics Lab a number of other programs that may be of interest to phoneticians, some of which have been described in a previous issue of WPP. In addition to the programs concerned with our research on articulatory-acoustic relations, the current versions of which are summarized in Table 1, we have constructed a formant synthesizer program, which is intended as a teaching tool. Synthesizers such as **Macintalk** that are commercially available or in the public domain are not very useful in teaching acoustic phonetics, in that students do not have any way of observing or modifying the acoustic parameters involved. They can only type in a sentence in orthography, observe the phonetic transcription that is produced by the text-to-phonetic-transcription rules (which is in itself informative, in that one can see where the system makes what one might call phonological errors), and then listen to the synthesized output. There is no way in which one can see what formant targets and transitions are associated with which segments, other than by making a spectrogram of the output. I have found that it makes a very good class assignment to require students to use Macintalk to synthesize a number of words, make spectrograms, and deduce what rules the system is using. But it would be much nicer to have the kind of system that is familiar to most of us who have worked on minicomputers, in which one can see the formants and other acoustic parameters graphically displayed on a screen, and then edit them and hear the results.

The program **MacSynth** was devised with these possibilities in mind. At the moment it is simply a formant synthesizer, enabling students to enter a set of formant frequencies and amplitudes, to see the damped wavetrains of the individual formants and the composite wave resulting from their combination, and to hear a vowel sound synthesized with these values and a pre-set fundamental frequency curve. It is also possible to read in a file containing the values for F1, A1, F2, A2, F3, A3, A4/5, and F0 at 10 ms intervals. In this way one can produce startling sentences such as "I owe you a yoyo" and "Will we weigh you?" We will be adding the possibility of fricative noises in the near future, and eventually hope to have a complete software synthesizer with full displays and graphically manipulatable parameters. But at the moment that (like **VocalCordVibrations**, our almost ready Macintosh program for demonstrating vocal cord movements, glottal flow, and glottal pulse spectra in terms of a two mass model) is just vaporware.

Preliminary versions of most of our other programs have been described in *Working Papers in Phonetics 61.* As we noted before most of them are designed as aids for investigating two research questions: (a) how can we model (specify in numerical terms) the dynamically changing shapes of the vocal tract? (b) what is the relation between these vocal tract shapes and the formant frequencies of the corresponding sounds? The versions listed in Table 1 are only slightly different from those previously released. Both compiled and source code versions of these programs are available.

We have been experimenting recently with using the source code as a teaching tool. I have long believed that (updating Lord Kelvin's philosophy) one does not really know anything about a process until one can describe it in terms of a computer model. Showing students sections of code that model a movement of the tongue or the vocal cords, or that perform a Fourier transform, has two useful functions: it makes the process explicit; and it demystifies the concept of a computer program. Of course one has to make the program a little less cryptic than usual, so that, for example, instead of using variables with short names like i, fcomp, etc, it is preferable to use longer names, as in the program sample in Figure 1. Even then, there is still a lot of teaching to do; but the notion of Fourier analysis is not simple, and has to be carefully explained.

```
=================================================================
HzFrequencyInterval := SampleRate div windowLength;     (* number of windows in a second          *)
numberOfFrequencyComponents := windowLength div 2;  (* max number of sine waves in a window *)
for frequencyIndex := 0  to numberOfFrequencyComponents do
   (* determine the amplitude of each component frequency                                          *)
   begin
      (* calculate the sine and cosine frequency ( in radians per sample point) for each component.   *)
      (* The actual value of this frequency depends on the SampleRate and is calculated later.        *)
      frequencyStep := TwoPi  *  frequencyIndex  / windowLength ;
      (* before summing, set the coefficients to zero                                                  *)
       cosCoefficient := 0.0;
       sinCoefficient := 0.0;
         for point := 0  to windowLength - 1 do
            (* sum the effect of each point                                                             *)
            begin
               cosCoefficient := cosCoefficient + Wave[point] * cos(point * frequencyStep);
               sinCoefficient :=  sinCoefficient + Wave[point] * sin(point * frequencyStep);
            end;

   (* dB  = 10* log to base10  of the power  spectrum  =  4.343 log to base e                          *)
    spectralAmplitude[frequencyIndex] := 4.343 * ln(realCoefficient **2  +  imaginaryCoefficient **2 );
   end;
=================================================================
```

Figure 1. Part of the Pascal code required to compute the discrete Fourier transform of the sequence of points representing a wave.

Teaching by means of such programs is very educational for many students in the humanities; and teaching object-oriented programming as is normal for the Macintosh is instructive for beginning computer scientists as well.

Finally we must note that there is now a considerably enlarged set of symbols in the font IPAplus. Both dot matrix (ImageWriter) and postscript (Laser Writer) versions of this font are available; the Laser Writer version was used to produce the IPA chart on the following page. Note that the font is called IPAplus because it contains various symbols and diacritics that have not been officially approved by the IPA, such as the click symbols | || ǂ ! ʘ used by most writers on Khoisan languages, and a number of other symbols such as ɡ (voiced velar lateral) which we have found necessary in our own work.

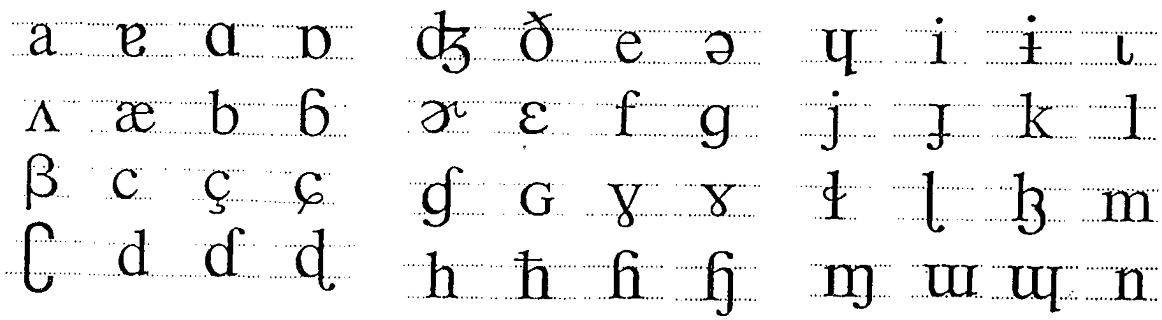

Figure 2. Examples of Laser IPA symbols available from SourceNet, as in Table 1.)

The version of this font used in this issue of WPP is in the public domain, and, like all the UCLA programs discussed in this report, is available from us for $5.00 or a Macintosh disk (subject, of course, to the usual constraints that it not be resold, or used in any way as part of a commercial product). We are well aware that there are several deficiencies in the shapes of the letters in this font; looking at large size versions shows that the curves are not always properly balanced, and that some of the supposedly straight lines actually have little glitches in them. A much better, professionally designed, set of fonts is **LaserIPA** (see Table 1 and Figure 2. These fonts are not copy protected; I thoroughly endorse them, and hope that, for the sake of the International Phonetic Association (who receive a royalty) everyone will buy their own copy. (And while I am doing my recommending bit, can I urge everyone to become a member of the IPA. We have a superb new journal coming out, and membership is only $20 or £10 p.a. from the Secretary, Dr. Peter Roach, Department of Linguistics and Phonetics, University of Leeds, Leeds, LS2 9JT, England.)

Acknowledgements

The current version of the program MacSynth was written by Neil Ticktin, who has also been very succesful in creating useful shells for other programs. I have learned a lot about programming from him. Many thanks also to Bruce Dath for developing the first version of the IPAplus laser font.

THE INTERNATIONAL PHONETIC ALPHABET (Revised to 1979) as available in IPAplus for the Macintosh, April 1987

CONSONANTS

		Bilabial	Labiodental	Dental, Alveolar, or Post-alveolar	Retroflex	Palato-alveolar	Palatal	Velar	Uvular	Labial-Palatal	Labial-Velar	Pharyngeal	Glottal
pulmonic air-stream mechanism	Nasal	m	ɱ	n	ɳ		ɲ	ŋ	ɴ				
	Plosive	p b		t d	ʈ ɖ		c ɟ	k g	q ɢ		k͡p g͡b		ʔ
	(Median) Fricative	ɸ β	f v	θ ð s z	ʂ ʐ	ʃ ʒ	ç ʝ	x ɣ	χ ʁ		ʍ	ħ ʕ	h ɦ
	(Median) Approximant		ʋ	ɹ	ɻ		j	ɰ		ɥ	w		
	Lateral Fricative			ɬ ɮ									
	Lateral (Approximant)			l	ɭ		ʎ						
	Trill			r					ʀ				
	Tap or Flap			ɾ	ɽ				ʀ				
(non-pulmonic air-stream)	Ejective	p'		t'				k'					
	Implosive	ɓ		ɗ				ɠ					
	(Median) Click	ʘ		ʇ ʗ									
	Lateral Click			ʖ									

DIACRITICS

- ˜ Velarized or pharyngealized ɫ, ɬ
- ̥ Voiceless n̥ d̥
- ̩ Syllabic
- ʰ Aspirated tʰ
- ̤ Breathy-voiced b̤, a̤
- ̪ Dental t̪
- ʷ Labialized tʷ
- ʲ Palatalized
- ˖ or ̟ Advanced u˖, u̟
- ̠ or ˗ Retracted i̠, ʝ̠
- ̈ Centralized ë
- ̃ Nasalized ã
- ͡ Simultaneous
- ˞ r-colored a˞
- ː Long aː
- ˑ Half-long aˑ

OTHER SYMBOLS

- ɕ, ʑ Alveolo-palatal fricatives
- ɧ Simultaneous ʃ and x
- ʃˢ Variety of ʃ resembling s, etc.
- c, ɟ may occasionally be used for tʃ, dʒ.
- ɺ Alveolar lateral flap
- ɚ = r-colored ə

VOWELS

	Front		Back
Close	i	ɨ	ɯ
	ɪ		
Half-close	e		ɤ
		ə	
Half-open	ɛ		ʌ
	æ		ɐ
Open	a		ɑ

Unrounded

	Front		Back
Close	y	ʉ	u
	ʏ	ʊ	
Half-close	ø		o
		ɵ	
Half-open	œ		ɔ
Open	ɶ		ɒ

Rounded

STRESS, TONE (PITCH)

- ˈ stress, placed at beginning of stressed syllable
- ˌ secondary stress
- ¯ high level pitch, high tone
- _ low level pitch, low tone
- ˊ high rising; ˏ low rising
- ˋ high falling; ˎ low falling
- ˆ rise-fall; ˇ fall-rise

Table 1. Programs mentioned or otherwise of interest

Name	Available from	Function
SoundWave	*Impulse Inc.	Record, playback, and editing of waveforms (further UCLA developments in progress)
TractMaker	UCLA	Creates files of vocal tract movements
CalcFormants	UCLA	Calculates the formant frequencies that would be produced by sequences of vocal tract shapes
MacSynth	UCLA	Synthesizes speech from files of formant specifcations or keyboard input. (Currently a very limited form of formant synthesis)
VocalCord vibrations	UCLA	Two mass model of vocal cord movements, glottal flow, and glottal pulse spectra; expected July 1987
FormantsTracts	UCLA	Displays the vocal tract shapes that might be associated with a given set of formant frequencies
PlotFormants	UCLA	Utility program for plotting formant frequencies
IPAplus	UCLA	Imagewriter and Laser Printer IPA fonts
Laser IPA	**SourceNet	Better Imagewriter and Laser Printer IPA fonts
MacinTalk	Public Domain (UCLA)	The Apple commissioned text to speech synthesis (not good, but the best available realtime software synthesis on a micro)
MooseTalk	Public Domain (UCLA)	A childish desk acessory that synthesizes MacinTalk phrases to keep one awake
Eliza	Public Domain (UCLA)	A free version of a famous program demonstrating the possibility of holding a conversation with a computer

* Impulse, Inc., 6870 Shingle Creek Pkwy., #112, Minneapolis, MN 55430
**SourceNet, P.O. Box 6767, Santa Barbara, CA 93160

Survey of phonetics computers in North American laboratories

Patricia Keating and Alice Anderton

This report summarizes some results of an August 1986 survey of North American phonetics laboratories, including a few non-academic ones, asking what computer hardware and software they used, and whether the software was available to others. Appendix A reproduces the questionnaire used, so that the results can be judged in context. A surprising number of labs responded to the survey, some with rather thorough information. Appendix B gives most aspects of these responses in database format. (Aspects related to details of waveform editors and to printers/plotters/etc. are generally omitted.) The laboratories responding to the survey can be determined from this appendix. In what follows below, some observations about these responses are made. These are surely, by now, already somewhat dated; for example, the situation at UCLA has changed a great deal since 1986. However, the survey should give a good picture as of about six months ago.

The overwhelmingly most popular type of computer is the DEC PDP 11, and among 11's, the 11/23 is narrowly, over the 11/34, the most common. (If the two ll/23's

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Table 1: Laboratories by machine

PDP 11/23 - Penn/Linguistics, Ohio State/Linguistics, Texas/Linguistics, Arizona State/Speech, SUNY Binghampton/Psychology, UCLA/Linguistics, Florida/IASCP

/34 - Washington/Speech, Berkeley/Linguistics, Brown/Linguistics, Alberta/Linguistics, S. Florida, Chicago/Cognitive Sci

/44 - San Diego/Linguistics

/73 - Vanderbilt, Washington/Speech, British Columbia/Speech, Alabama/Speech

/83 - Indiana/Linguistics

VAX 11/730 - Calgary

/750 - Indiana/Psychology, MIT/RLE, San Diego/Linguistics

/780 - Speech Plus, BBN, Brown/Cognitive Sci

Other - NRC Canada, Michigan/Speech, Berkeley/Linguistics, Alberta/ Linguistics, British Columbia/Speech, Louisiana State, Purdue/Speech, I Indiana/Linguistics, Kurzweil AI, San Diego/Linguistics that have been upgraded to 73 and 83 status are included, the 11/23's margin is more secure.) The various other PDP 11's are each about as common as the various VAX machines.

Details on other hardware, including Analog to Digital converters, co-processors, and screen display, are given in Appendix B. Since brand names or models were not specifically requested, they were rarely given.

Not surprisingly, given the hardware, the most common operating system is RT-11. Other common operating systems are VMS (6 sites) and UNIX (5 sites).

Speech software is most commonly custom done in each lab. Commercial labs use custom software that is not available to others, so the discussion of software excludes these labs. Not surprisingly, the most frequently acquired speech software is ILS, which 9 labs own. Other acquired systems are the Brown BLISS programs for DEC machines (4 other labs), the MIT Spire system for LISP machines, Carnegie-Mellon programs, and programs from HP and Bell (1 lab for each of these). However, many labs indicate that their custom software, though often less than a whole system, would be made available at cost. This information is also included in Appendix B. Because the Brown system appears to be the most-distributed non-commercial system, more details about it are included in the Appendix than are included for other labs' custom software.

There is some diversity in the editing and analysis capabilities of the many systems described. While everyone has waveform editors, they differ quite a bit. Most have 2 cursors on the screen, controlled from the keyboard, which allow pieces of files to be displayed and played, and timing measurements made. Scrolling, cut-and-paste, and analog cursor control are less universally found, though still common. The most extensive editing capabilities appear to be those at Berkeley, Brown, Indiana, Louisiana State, San Diego, and Texas. Almost all labs report FFT and LPC analysis, some kind of f_0 measurement, and Klatt synthesis.

A separate questionnaire was included for personal computers, with a view to seeing how far their use for speech had progressed. Some of these data are summarized in Table 2. IBM PC, PC/XT, and PC/AT machines are common, though Zenith and Erickson clones are also reported. Three labs use AT&T machines, while only UCLA reports using a Macintosh. Where D-to-A board brands are reported, they show no concensus. While many other labs indicated that they used PCs, only these few use them for speech. Furthermore, they tend to do so with acquired software. ILS, Micro Speech Lab, and SoundCap are each used by 2 labs. UCLA also uses CSpeech (Wisconsin). Labs that report using custom software are Brown (to run experiments), SUNY Binghampton, U. Mass (waveform and f_0), Illinois (language teaching) and Purdue; other labs report current or future software development efforts, including a major project jointly by Calgary and Alberta.

Table 2: Micros for Speech

IBM		
PC	U. Illinois Language Lab	custom, for language teaching
XT	Alberta	software development
	Michigan	ILS
	Brown (DT board)	run experiments
	UCLA (IBM, Tecmar boards)	CSpeech
AT	NRC Canada	no info
	Alberta (Tecmar board)	SoundCap
	SUNY Binghampton	ILS; custom; development
AT&T		
6300	Ohio State	various sources
	U. Mass	waveform and f_0
6300+	Purdue	custom
Clones		
Zenith	LSU	Micro Speech Lab
Erickson	ASU	Micro Speech Lab
Zenith	UBC	no info
Apple		
Mac Plus	UCLA	various

APPENDIX A: Survey

APPENDIX B: Survey responses

Responses to the survey, parts I and II, were entered into the Microsoft File database program using the format shown below, in fields representing computer, operating system, analog-to-digital converter, screen specifications, memory capacity, coprocessor, software capabilities, availability of software, and additional comments.

APPENDIX A: Survey

APPENDIX B: Survey responses

Responses to the survey, parts I and II, were entered into the Microsoft File database program using the format shown below, in fields representing computer, operating system, analog-to-digital converter, screen specifications, memory capacity, coprocessor, software capabilities, availability of software, and additional comments.

Survey of Phonetics Laboratories

I. Mini-computers and larger

We use the following computer:

- ___ DEC PDP 11/ _____
- ___ VAX _________
- ___ Sun _________

Editing:

- ___ display waveform
- ___ mark off part of waveform
  - ___ using cursors (# at one time on screen: ____)
    under ___ keyboard control
    ___ knob
    ___ mouse
    ___ other: __________
- ___ display this piece
- ___ play this piece
- ___ scroll through file
- ___ cut-and-paste pieces
- ___ make timing measurements
- ___ other: ______________________________

Analysis:

- ___ f_0 (technique: ____________________)
- ___ intensity
- ___ FFT
- ___ LPC
- ___ running spectra (waterfall display)
- ___ formant tracking
- ___ digital spectrogram
- ___ inverse filtering
- ___ Other: ______________________________

Analysis is available as:

- ___ graphical displays only
- ___ numbers on screen
- ___ numbers in ASCII file

___ formant synthesis
___ articulatory synthesis
___ other modeling: ____________________

___ run experiments on line
___ produce experimental stimulus tapes
___ statistical analysis

___ other: ______________________________
____
____

Comments and/or other information (including difficulties encountered actually trying to use software; software currently under development; what you most <u>often</u> use the computer for)

____
____
____
____
____
____
____
____
____
____

II. Just for Micro-computers

We use the following:

___ Macintosh
___ IBM: PC XT AT
___ IBM clone ____________
___ AT&T
___ Amiga
___ Other: ____________

with the following A/D hardware:

___ provided with computer (e.g. Macintosh)
___ IBM Data Acq. & Control
___ Data Translation
___ Tecmar Lab-Master
___ Other: ____________

and filters: ____________

and the following other hardware:

___ coprocessor: ____________
___ data storage: ____________ capacity: ____________
___ graphics monitor: ____________
e.g. ___ IBM color
___ IBM enhanced color
___ Hercules card
printer:
___ dot matrix
___ laser
Other: ____________
____

and the following operating system: ____________

to run the following software:

___ ILS
___ CSpeech (Paul Milenkovic)
___ Micro Speech Lab (Vancouver)
___ Nirvonics
___ MacAdios
___ SoundCap
___ other from outside our lab: ____________
* ___ custom done in our lab: ____________ *
* We would consider making available *
* ___ executable version *
* ___ source code in ____________ (language) *
* approximate cost: *
* if possible, some idea of portability to other hardware configurations: *
* ____________ *
* ____________ *

able to do the following tasks (no need to answer if you only use commercial software):

I/O:
___ digitize speech
___ digitize multiple channels (e.g. physiological)
___ play back speech in 1 ___ 2 ___ channels
___ store signal in file, and access it from file
Editing:
___ display waveform
___ mark off part of waveform
___ using cursors (# at one time on screen: ____)
___ under keyboard control
___ knob
___ mouse
___ other: ____________

___ display this piece
___ play this piece
___ scroll through file
___ cut-and-paste pieces
___ make timing measurements
___ other: ________________________

Analysis:

___ f_0 (technique: ____________________)
___ intensity
___ FFT
___ LPC
___ running spectra (waterfall display)
___ formant tracking
___ digital spectrogram
___ inverse filtering

___ formant synthesis
___ articulatory synthesis
___ other modeling: ________________________

___ run experiments on line
___ produce experimental stimulus tapes
___ statistical analysis

___ other: ____________________________________
____
____

Analysis is available as:

___ graphical displays only
___ numbers on screen with screen-dump to printer
___ numbers in ASCII file

We use the micro as a terminal for a larger system

Comments and/or other information (including difficulties encountered actually trying to use software; software currently under development; what you most often use the computer for):

____
____
____
____
____
____
____
____

This survey was completed by:

____
(lab)

____
____
(address)

Person to contact for more information: ________________________

Responses to the survey, parts I and II, were entered into the Microsoft File database program using the format shown below, in fields representing computer, operating system, analog-to-digital converter, screen specifications, memory capacity, coprocessor, software capabilities, availability of software, and additional comments.

Alabama, University of/Biocommunications

Cptr: PDP 11/73 (2) — *OS:* RT-11

A/D: 12-bit — *Scr:* Hirex100/Graph-on/Tekt4012

Memory: — *Co-Pr:*

Softw: multi-channel; Klatt synthesis; fØ, LPC; digital spectrogram

Avail:

Alberta, University of, Edmonton/Linguistics (a)

Cptr: PDP 12 — *OS:* RT-11

A/D: 16K, 10-bit — *Scr:*

Memory: 32K — *Co-Pr:*

Softw: custom Fortran system includes Klatt synthesis, full editor and analysis, 2-channel output

Avail: at cost

Alberta, University of, Edmonton/Linguistics (b)

Cptr: PDP 11/34 — *OS:* RT-11

A/D: 20K, 12-bit — *Scr:*

Memory: 256K — *Co-Pr:*

Softw: ILS, BLISS (Brown University)

Avail:

Arizona State University/Hearing Research Lab

Cptr: PDP 11/23 — *OS:* RT-11

A/D: 12-bit Data Translation — *Scr:* Retrographics 480 x 640

Memory: — *Co-Pr:*

Softw: custom system includes Klatt, filtering, run experiments on-line; 2-channel output; in editor, automatic finding of zero crossings.

Avail: at cost; requires DT A/D.

Bolt, Beranek, Newman, Inc.	
Cptr: VAX 11/780	*OS:* VMS
A/D: 20K, 12-bit	*Scr:* BBN bitgraph
Memory: 8MB	*Co-Pr:* yes
Softw: ILS	
Avail: no	

Bolt, Beranek, Newman, Inc.	
Cptr: Symbolics LISP machines	*OS:* Lisp machine
A/D:	*Scr:* LISP machine graphics
Memory:	*Co-Pr:*
Softw: SPIRE (MIT)	
Avail:	

British Columbia, University of/Audiology and Speech Sciences (a)	
Cptr: PDP 11/73	*OS:* RSX, UNIX, other (?)
A/D: 50K, 12-bit	*Scr:* 1024 x 800
Memory: 4MB	*Co-Pr:*
Softw: BLISS (Brown U.) FFT, LPC; custom being implemented for other functions; Wigner distribution; formant & artic. synthesis; run experiments	
Avail:	

British Columbia, University of/Audiology and Speech Sciences (b)	
Cptr: PDP 12	*OS:*
A/D:	*Scr:*
Memory:	*Co-Pr:*
Softw:	
Avail:	

Brown University/Cognitive & Linguistic Sciences (a)	
Cptr: PDP 11/34	*OS:* RT-11
A/D: 30K, 10-bit Data Transl.	*Scr:* 1024 x 1024 vector
Memory: 250K	*Co-Pr:*
Softw: custom Fortran system (BLISS) includes multi-ch I/O; 8-cursor editor w/key, mouse, bitpad control; all analysis exc. inverse filtering; Henke and Klatt synthesis; critical band analysis.	
Avail: requires RT-11 v.5, DT hardware; $50 cost. Used elsewhere.	

Brown University/Cognitive & Linguistic Sciences (b)	
Cptr: VAX 11/780	*OS:* VMS
A/D:	*Scr:* Tektronix
Memory:	*Co-Pr:*
Softw: BLISS system; see above.	
Avail: See above.	

Brown University/Cognitive & Linguistic Sciences (c)	
Cptr: Micro-Vax II	*OS:* VMS
A/D: 50K, 12-bit	*Scr:* 1024 x 1024 bit-mapped
Memory: 9 MB	*Co-Pr:*
Softw: ?	
Avail:	

Calgary, University of (Canada)	
Cptr: PDP 11/23 plus	*OS:* RT-11
A/D:	*Scr:* VT-103 (2)
Memory:	*Co-Pr:*
Softw: run experiments	
Avail:	

Calgary, University of (Canada)	
Cptr: VAX 11/730	*OS:* VMS
A/D: 12-bit	*Scr:*
Memory:	*Co-Pr:* array
Softw: ILS; BLISS (Brown University)	
Avail:	

California, University of, Berkeley/Linguistics	
Cptr: Chi-5	*OS:* ?
A/D:	*Scr:*
Memory: "tons & tons"	*Co-Pr:* own array
Softw: real-time fØ; int., LPC	
Avail:	

California, University of, Berkeley/Linguistics	
Cptr: PDP 11/34	*OS:* RT-11
A/D: 44K, 12-bit	*Scr:* 1024 x 1024
Memory: 96K	*Co-Pr:*
Softw: custom Fortran system includes synthesis, modeling, multi- channel, formant tracking	
Avail: modular and portable except for I/O	

California, University of, Berkeley/Linguistics	
Cptr: HP 9836	*OS:* UNIX
A/D: 33K, 12-bit	*Scr:* color 1000 x 1000
Memory: 3MB	*Co-Pr:* Motorola
Softw: from HP ("SADIE") and Bell: no longer supported; editor, fØ; int., FFT, LPC, formant tracking, digital spectrogram, voicing detection; extensive interactive statistics	
Avail:	

California, University of, Los Angeles/Linguistics	
Cptr: PDP 11/23	*OS:* RT-11
A/D: 20K,12-bit Data Tr	*Scr:* 1024 x 1024
Memory: 128K	*Co-Pr:* Analogic array
Softw: custom Fortran system includes inverse filtering, breathiness analyses, Holmes synthesis parameter editor.	
Avail: yes but not very portable	

California, University of, San Diego/Linguistics (a)	
Cptr: VAX 11/750	*OS:* UNIX
A/D: DSC, 50 kHz, 16-bit	*Scr:* 1024 x 1024
Memory: 8 MB	*Co-Pr:* DEC
Softw: Custom C system includes Klatt, formant tracking, digital spectrogram	
Avail: $100 per tape; used elsewhere.	

California, University of, San Diego/Linguistics (b)	
Cptr: PDP 11/44	*OS:* UNIX
A/D:	*Scr:*
Memory:	*Co-Pr:*
Softw:	
Avail:	

Chicago, University of/Dept. Behavioral Sciences, Cognitive Science Lab	
Cptr: PDP 11/34	*OS:* RT-11
A/D: 10K, 12-bit	*Scr:*
Memory: 128K	*Co-Pr:*
Softw: "public domain" speech routines for editing, 2-ch output; FFT, LPC, formant tracking, Klatt, run experiments.	
Avail:	

Florida, University of, Gainesville/IASCP	
Cptr: PDP 11/23	*OS:* RSX
A/D: 25K, 12-bit	*Scr:* 400 x 280
Memory: 512K	*Co-Pr:* DEC
Softw: ILS, other commercial; custom for speaker ID	
Avail:	

Indiana University /Linguistics (a)	
Cptr: VAX with Apollo work-stations	*OS:* UNIX & Apollo Aegis
A/D: DSC-200 16K in VAX	*Scr:* 800 x 1000
Memory: 4MB	*Co-Pr:*
Softw: Ron Cole (CMU) UNIX acoustic software	
Avail: Ron Cole/requires UNIX	

Indiana University/Linguistics (b)	
Cptr: PDP 11/83 (< 11/23)	*OS:* UNIX 2.9 BSD
A/D: none	*Scr:*
Memory: 1 MB	*Co-Pr:* Sky
Softw: "no acoustics work"	
Avail:	

Indiana University/Psychology (Speech Research Lab) (a)	
Cptr: LISP machine- Symbolics	*OS:* LISP-machine
A/D:	*Scr:*
Memory: 2MB	*Co-Pr:*
Softw: SPIRE system	
Avail:	

Indiana University/Psychology (Speech Research Lab) (b)	
Cptr: VAX 11/750	*OS:* VMS
A/D: 20k, 16-bit	*Scr:* 340 x 720 Retrographics
Memory: 8MB	*Co-Pr:*
Softw: ILS; custom Fortran system includes editor, Klatt synth, FFT + LPC, formant tracking, digital spectrogram (no fØ)	
Avail: source or executable	

Indiana University/Psychology (Speech Research Lab) (c)	
Cptr: PDP 11/34A (3)	*OS:* RT-11
A/D: 20k, 10-bit	*Scr:*
Memory: 256K	*Co-Pr:*
Softw: custom Fortran system as for VAX includes 2-channel D/A	
Avail: source or executable	

Kurzweil AI	
Cptr: Mass-Comp (6)	*OS:* UNIX
A/D: 16K, 12/16-bit	*Scr:* color 1024 x 1024
Memory: 3-4 MB	*Co-Pr:*
Softw: custom editor, digital spectrogram, filter bank analysis	
Avail: no	

Louisiana State University, Baton Rouge	
Cptr: Perkin Elmer 3210	*OS:* own
A/D: 100K, 12-bit	*Scr:* 1024 x 1024 Tektronix
Memory: 1MB	*Co-Pr:*
Softw: custom Fortran system for multi-user, real-time speech (multi-channel I/O; real-time analysis (all) and formant synthesis), run experiments, make tapes, do statistics	
Avail: source	

Massachusetts Inst. of Technology/Research Lab Electr. (Speech Commun)	
Cptr: VAX 11/750	*OS:* VMS
A/D: 10K, 12-bit	*Scr:* 500 x 800
Memory: 4 MB	*Co-Pr:* VAX
Softw: custom C system includes input, minimal editor, Klatt, fØ & int., FFT & LPC, formant track and digital spectrogram, critical band spectra, good documentation.	
Avail: free in either version, but not very portable	

Michigan, University of	
Cptr: IBM S9000/CS	*OS:* CS-DOS
A/D: 100K, 16-bit	*Scr:*
Memory: 1MB	*Co-Pr:*
Softw: custom: input, minimal editor, run experiments	
Avail:	

National Research Council, Canada	
Cptr: Concurrent Computer Corp 3230	*OS:* UNIX
A/D: 40K, 14-bit	*Scr:* 512 x 512
Memory: 10 MB	*Co-Pr:* yes
Softw: custom system ("VISA"): partial I/O, partial editor; fØ, FFT LPC, formant tracking, digital spectrogram, cochlear modeling	
Avail: any UNIX system	

New York , State University of, Binghamton/Psychology	
Cptr: PDP 11/23	*OS:* RT-11
A/D: 20K, 12-bit	*Scr:*
Memory:	*Co-Pr:*
Softw: ILS; Klatt	
Avail:	

Ohio State University/Linguistics (a)	
Cptr: PDP 11/23	*OS:* RT-11
A/D: 50k,12-bit Data Tr	*Scr:* Tektronix hardcopy
Memory: 128K	*Co-Pr:*
Softw: ILS (used for fØ)	
Avail:	

Ohio State University/Linguistics (b)	
Cptr: Synclavier II, New Eng. Digital	*OS:* own
A/D: own 50k,16-bit	*Scr:* 640 x 480
Memory: 128K	*Co-Pr:*
Softw: waveform editing and running experiments	
Avail:	

Pennsylvania, University of/Linguistics	
Cptr: PDP 11/23 (plus 2 others)	*OS:*
A/D: 12-20K, 12-bit	*Scr:*
Memory: 1MB	*Co-Pr:*
Softw: ILS; Klatt synthesis	
Avail:	

Purdue University/Audiology & Speech	
Cptr: DG Nova 4x	*OS:* DOS
A/D: 16K, 12-bit	*Scr:* 4010 Tektronix
Memory: 128K	*Co-Pr:* DG FP
Softw: ILS, Klatt; custom I/O (2-channel) and make tapes (ILS is a problem here; moving to micros)	
Avail:	

South Florida, University of, Tampa	
Cptr: PDP 11/34	*OS:* RSX
A/D: 10K, 12-bit	*Scr:* 780 x 1024
Memory: 64K	*Co-Pr:* yes
Softw: modified ILS	
Avail:	

Speech Plus, Inc.	
Cptr: VAX 11/780	*OS:* VMS
A/D: 10K, 12-bit	*Scr:* VT-240 (640 x 400)
Memory: 4MB	*Co-Pr:*
Softw: ILS; also custom system including Klatt synthesis, LPC, formant tracking, digital spectrogram (many micros as terminals)	
Avail: no	

Texas, University of, Austin/Linguistics	
Cptr: PDP 11/23 MINC	*OS:* RT-11
A/D: 24K, 12-bit	*Scr:* 800 x 1024
Memory: 256K	*Co-Pr:*
Softw: custom Fortran & Macro system includes full editor, FFT & waterfall (not LPC), spline fit and peak picking from FFT; formant synthesis, run experiments	
Avail: at cost; joystick-based case not portable	

Vanderbilt University/Speech Science Lab	
Cptr: PDP 11/73 (<11/23)	*OS:* RT-11, RSX
A/D: 100K, 12-bit	*Scr:*
Memory: 256K	*Co-Pr:* DEC
Softw: custom Fortran/Assembly system with Klatt synthesis, digital spectrogram, fØ + int., FFT, LPC, waterfall, run experiments.	
Avail: at cost	

Washington, University of/CDMRC (a)	
Cptr: PDP 11/34	*OS:* RT-11
A/D: 30K, 14-bit	*Scr:* VT-11
Memory: 128K	*Co-Pr:*
Softw: custom Fortran IV system includes 2-channel output, editor, fØ, int., FFT, LPC, run experiments, produce tapes	
Avail: available but not very portable	

Washington, University of/CDMRC (b)	
Cptr: PDP 11/73	*OS:* RT-11
A/D: 50K, 12-bit	*Scr:* 512 x 1024
Memory:	*Co-Pr:*
Softw: BLISS (Brown U.), also some custom (can't tell what is in which)--multi-channel I/O; partial editor; fØ, int., LPC; run experiments & produce tapes.	
Avail: custom Fortran IV available	

A Survey of Phonological Features

Patricia Keating

This review is intended to provide a convenient but detailed summary of the current status of various segmental features[1]. It covers all the features given in The Sound Pattern of English (Chomsky & Halle 1968, henceforth SPE), and several features proposed since then. In a sense it is an update of Kenstowicz & Kisseberth (1979)'s discussion (henceforth K&K), though with more emphasis on phonetics. K&K do an excellent job of supplementing SPE with more and better arguments for many of the natural classes given by the SPE features, and these arguments are generally cited, not repeated, in this paper. K&K also give a good discussion of the overall what and why of features, which is not attempted here. This paper, therefore, does not entirely replace K&K's treatment of features. Other discussions of the SPE features from earlier well-known texts are also referred to, but are not entirely repeated, here. Therefore the reader may also want to consult Anderson (1974), Hyman (1975), Sommerstein (1977), Halle & Clements (1983), or Anderson (1985) either for a general introduction to features, or in regard to specific citations throughout this paper. In particular, Hyman (1975) and Anderson (1985) can be recommended for a summary of the acoustics-based feature system of Jakobson, Fant & Halle (1951/1963), which SPE replaced. However, this paper is intended to be useful to the student who has not already read these (or other) references. Finally, this survey is concerned only with the features themselves, and so discusses new ideas about the structure and geometry of feature representations only as it affects the inventory of segmental features.

I. Place of articulation for consonants

With SPE there was a shift from acoustic to articulatory features, and specifically to a focus on the active articulator -- its state, or configuration, rather than its location in traditional place of articulation descriptions. The SPE features for place of articulation were quite innovative; they have also been subject to various proposals for revision.

A. Labials

1. [anterior]. This feature was proposed in SPE to divide places of articulation into alveolar-and-fronter vs. palatoalveolar-and-backer. K&K and others have expressed reservations about this feature in that, in grouping together labials, dentals, and alveolars, it seems to refer neither to any natural classes in rules nor to any single active articulator; it is only used for representing lexical distinctions. We should note that [+anterior] may have an acoustic correlate: a diffuse spectrum (Stevens & Blumstein 1978), though whether this property draws a dividing line precisely where [+anterior] does is doubtful. In recent unpublished work,

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[1] Some of the material here is also included in my paper on the phonetics-phonology interface (UCLA Working Papers in Phonetics 62, Dec. 1985).

Steriade has proposed that [anterior] be limited to distinguishing among coronals, thus taking care of K&K's reservations.

2. [labial]. This feature represents an innovation since SPE, and has been proposed in two different senses. Anderson (1974) proposes it primarily to refer to labial places of articulation, that is, to replace [-anterior, -coronal] as part of the representation for labials (bilabials, labiodentals, labial-velars, and other double articulations). He also uses it to refer to some types of rounding, but not to rounding in general. However, the more common intention with a feature [labial] has been a "cover feature" that would relate labial consonants and [+round] segments (rounded vowels and glides, and labialized consonants). Vennemann & Ladefoged (1971) first proposed this feature for cases such as [w] becoming [v], for [m] and [v] becoming [u], for [ɣ] becoming [v] between rounded vowels, and for front vowels becoming rounded before labial or rounded consonants. Hyman (1975) argues for such a cover feature on the basis of Igbo reduplication, in which non-labial stem consonants reduplicate with a high front unrounded vowel, while labial stem consonants reduplicate with a high back rounded vowel. "Labial" consonants here include bilabials, labiodentals, labialized velars, and labiovelars. Although K&K think that assimilation-based arguments for [labial] are generally suspect, such a feature to relate all segment types involving the lips seems to have been rather widely accepted, e.g. Halle (1983).

3. Bilabials vs. labiodentals. These are the two places of articulation included within labials. They must have distinct representations because a few languages contrast these kinds of consonants (for example, Ewe has voiced and voiceless fricatives of both types -- see Ladefoged 1968, 1971, or Ladefoged & Maddieson 1986). Other languages with at least one contrasting pair of fricatives listed in UPSID (the UCLA Phonological Segment Inventory Database, Maddieson 1984) are Iai, Kanuri, and Tarascan, the latter two having more marginal contrasts. In SPE, one feature used to provide this distinction was [strident], with labiodentals noisier (i.e. [+strident]) than bilabials ([-strident]). Another possibility also given in SPE is [distributed], since bilabial constrictions are arguably slightly more distributed than labiodental constrictions. (A distributed articulation is one in which there is a relatively broad constriction in the direction of airflow.) This feature is used instead of [strident] by Stahlke (1971) in his account of the Kpando dialect of Ewe. However, use of either of these features runs up against K&K's two objections to [anterior] that were mentioned above: first it predicts some unlikely natural classes (e.g. in English, non-distributed alveolars and labiodentals as against distributed dentals and palatoalveolars), and second it cuts across articulators. If these features are limited to coronal distinctions (see below), then these objections are avoided, but labials and labiodentals are less straightforwardly distinguished.

The resulting treatment of the bilabial vs. labiodental fricatives basically consists of relying on other, non-place, features for the place

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[2] For example, in the Yerwa or Maiduguri dialect of Kanuri, the relation is allophonic rather than contrastive (Hutchison 1981).)

distinction. When two or more feature differences accompany a segment contrast, it is not always clear which feature should be treated as contrastive, and which redundant (predictable) for that contrast. Thus Sagey (1986) suggests the manner feature [continuant] to distinguish bilabials from labiodentals, treating the place difference as redundant. This works fine for English and many other languages (at least above the level of phonetic detail). Labiodental stops are not found in languages, and from Maddieson (1984) we learn that bilabial stops most often contrast with labiodental fricatives; thus the contrast in stop vs. fricative ([continuant]) can often replace the place of articulation contrast. In several other cases in UPSID a voiced bilabial fricative contrasts with a voiceless labiodental one, so the contrast can be represented as one of voicing. But neither of these will work when consonants at the two places have the same manner and voicing, as in Ewe and the other languages cited above. It is clear from Ladefoged (1968)'s description of Ewe that the distinction is not due to some other manner feature, such as [sonorant] or [tense]. Furthermore, according to Stahlke (1971), there is no internal phonological evidence from Ewe to indicate what feature is involved in the contrast. Some new feature seems to be needed just to characterize this rare contrast, a curious situation.

B. Coronals

Coronal sounds are articulated with the front or blade (including the tip) of the tongue, and in SPE include dental, alveolar, retroflex, and palatoalveolar places of articulation. SPE used the features [anterior, strident] to distinguish among the English coronals (i.e. the dental, alveolar, and palatoalveolar fricatives), and the feature [distributed] to make additional distinctions. Several issues have arisen in relation to the coronals.

1. [coronal], [grave], and palatals. For consonants, SPE gave up the Jakobson, Fant & Halle acoustic feature [grave] in favor of the not-quite-equivalent articulatory feature [coronal]: most sounds that were [+grave] are [-coronal]. The difference is that while palatals were [-grave], they were said to be [-coronal]. This change in the natural classes elicited a furor of complaints, either that palatals pattern with dental and alveolars ([+coronal]), or that velars alternate with labials (e.g. Hyman 1973, Vago 1976, Odden 1978, Becker 1978). Halle & Stevens (1979) proposed to redefine [+coronal] to include palatals, showing in the process that phonetic definitions for features can be produced or discarded on demand (more on this below). The only potential distinction then between old [grave] and new [coronal] concerns the representation of uvular and pharyngeal places. These are certainly [-coronal], but were unspecified for [grave] in the Jakobson, Fant, & Halle system (as discussed in Jakobson 1957). Nonetheless, on all of the definitions of gravity given in Jakobson, Fant & Halle (1951/1963), uvulars and pharyngeals are plausibly [+grave]. On this interpretation, the new definition of [coronal] is exactly equivalent to [grave].

2. Distinctions among coronals. SPE, with its focus on active articulators, rejected features taken from the traditional place of articulation continuum along the roof of the mouth. Instead, three features

are in effect used to distinguish among coronal places: [anterior], [distributed], [strident]. The last feature is useful only for fricatives, so we will first consider other coronal distinctions.

a. Non-fricative coronals. [anterior] divides the coronals at the alveolar ridge: alveolars and dentals are [+anterior], while the various post-alveolars are [-anterior]. Lahiri & Blumstein (1984) claim that for non-fricatives, there is no contrast between palatal and palatoalveolar. On their account, this leaves the following distinctions to be made among four categories of non-fricatives:

[+anterior] -- dental must be distinguished from alveolar
[-anterior] -- retroflex must be distinguished from palatal or palatoalveolar

Certain Dravidian languages and most Australian languages use all four categories contrastively for oral and nasal stops, and for laterals: dental, alveolar, retroflex, and palatoalveolar or palatal. The alveolars and retroflexes often pattern together in opposition to the dentals and palatals, giving evidence that a further binary feature is needed. The SPE feature for these distinctions is [distributed]. Strictly speaking, this is a manner feature rather than a place of articulation feature, but the manner of the active articulator is taken as the basic dimension. For coronals, this feature is equivalent to the traditional distinction between apical (alveolar and retroflex, [-distributed]) and laminal (dental and palatal or palatoalveolar, [+distributed]). If we seriously adhered to the proposal that features should not cut across articulators, then the traditional name [laminal] would be preferable to [distributed], since other articulators could in principle distinguish more from less "distributed" constrictions.

Challenges to this four-category system are presented by some of the data on place of articulation given by Ladefoged & Maddieson (1986). Some of their cases seem to involve other features as well, such as apical dental vs. apical alveolar clicks, and palatoalveolar vs. palatal stops, where in both cases affrication may occur. If these contrasts involve frication, then they can be treated under the system of fricative features, discussed below, which allow more contrasts to be represented. Other of Ladefoged & Maddieson's cases are presented tentatively on the basis of a single description in the literature, such as apical retroflexes vs. sublaminal retroflexes, and apical dental vs. apical alveolar laterals. Finally, a contrast in Malayalam between palatoalveolar and palatal nasals is cited from Mohanan & Mohanan (1984), exactly what Lahiri & Blumstein (1984) say does not occur. So depending on how these cases hold up, the feature system described above may not suffice for coronal non-fricatives.

Even if it turns out that the palatoalveolar - palatal distinction is not used for minimal contrasts, it is still desirable to characterize the difference for the systematic phonetic level of representation. In Keating (in preparation) I present cross-language evidence gleaned from the UCLA X-ray database (in this issue of WPP) which suggests that palatals are articulatorily more complex than palatoalveolars. I propose that palatals are simultaneously coronal and [+high, -back], while palatoalveolars are coronal but unspecified for the tongue body features. This claim needs additional testing, however.

b. Fricative coronals and [strident]. Fricatives, like non-fricatives, contrast in [anterior] and [distributed]. As it happens, Australian languages typically lack fricatives altogether, and so do not offer series parallel to their stops and laterals, but many other languages do provide relevant contrasts. For example, Catford (in progress) describes four categories of coronal fricatives in Ubykh that appear to be distinguished by these two features.

Fricatives seem to occur at more places of articulation than do the four stop categories; for example, we find both palatoalveolar and palatal places within a language. Since both are [-anterior, +distributed], some third feature is needed to distinguish these contrasting categories. In SPE, the feature [strident] was used for this (and other) contrasts, refering to greater noisiness resulting from various articulatory considerations. The earlier use of this feature by Jakobson, Fant, & Halle referred specifically to an articulation in which an airstream is directed to impinge on an obstacle, creating extra turbulence. This is essentially the same definition as in Halle & Stevens (1979; see also Shadle 1984); although they called this feature [grooved], in line with its articulatory definition, the name [strident] seems likely to persist (see Stevens 1983, Stevens et al. 1986), though [sibilant] may also be used with this meaning. Alveolar, palatoalveolar, and retroflex fricatives are all strident. This feature thus separates palatal from palatoalveolar fricatives with minus vs. plus values of [strident]. Also, in SPE and most treatments of English, [strident], not [distributed], is used for the dental vs. alveolar fricative contrast. Furthermore, anterior distributed (dental) coronals can also contrast in stridency, ie. [θ] can have a strident counterpart, which Halle & Stevens identify with the "tongue tip down" [s]. It could also be identified with a dental sibilant [s̪]. The following chart summarizes these coronal fricative distinctions. Additional features would be needed if all differences between fricatives across languages were to be described (e.g. Ladefoged & Maddieson 1986).

	θ	s	s̪	ʃ	ṣ	ç
anterior	+	+	+	−	−	−
distributed	+	−	+	+	−	+
strident	−	+	+	+	+	−

Besides giving the needed place of articulation distinctions, the feature [strident] gives needed fricative natural classes, for example, for the English plural (etc.) rule. However, [strident] cannot make these place distinctions for other manners of consonants. That is why the possible occurrence of such contrasts in nasals, discussed in the preceding section, is problematic for the system.

The fact that there are more fricative than non-fricative contrasts, including the [strident] contrasts, makes it possible that place of articulation may not be precisely analogous in fricatives and non-fricatives. One principle that would produce such a difference between places is what is sometimes called dispersion: it is often suggested that speakers may emphasize the phonological contrasts of their language by exaggerating the phonetic differences involved. If this is done for the fricative contrasts, then we might expect the exact details of even the "same" place of articulation to differ slightly between coronal fricatives and non-fricatives, with more extreme values for the fricatives.

A related observation about coronal places is that one advantage of using manner features for fine place distinctions is that there is no need to specify where, for example, "dental" ends and "alveolar" begins in the mouth. The only distinction that must be made is the line between alveolars and palatoalveolars or retroflexes, that is, the boundary between [+anterior] and [-anterior].

C. Tongue body features for place

1. Vowel features for primary places. Chomsky & Halle proposed that all articulations involving the tongue body be described by the features [high,low,back]. Such articulations include not only vowels and vowel-like secondary articulations, but also consonant primary places of articulation from palatal back to pharyngeal. The features work as follows.

	palatals palatalization [i]	velars velarization [u]	uvulars uvularization [o]	pharyngeals pharyngealization [ɑ]
high	+	+	-	-
low	-	-	-	+
back	-	+	+	+

Thus palatals, palatalization, and high front vowels are said to share similar tongue body articulations, while velars, velarization, and high back vowels are said to share a different set of similar tongue body articulations. One motivation is the patterning of velars with back vowels, and palatals with front vowels: rules of velar fronting in front vowel contexts can be stated as assimilations with these features. K&K (1979:250) offer arguments for the parallel treatment of uvulars and pharyngeals. Evidence that uvulars are more like mid vowels comes from rules in Greenlandic Eskimo, Quechua, and other languages that lower high vowels to mid in a uvular context. Evidence that pharyngeals are more like low vowels comes from Semitic rules giving /ɑ/ in pharyngeal contexts.

The whole area of back consonant distinctions seems unclear. Since SPE, various proposals have been made to split off the pharyngeals, using for them features like [ATR] or [Constricted Pharynx] instead of [+back,+low]. Most recently, Steriade (1987) adopts this proposal as part of giving up use of the SPE vowel features for consonants.

A problem with the SPE way of distinguishing velars vs. uvulars is that phonetically it would seem that velars and uvulars are really on a diagonal, not a vertical, line, with uvulars being both lower and backer than velars. Phonologically, languages appear to choose one direction as the nominal one. The example used by K&K shows that Eskimo treats uvulars as being lower than velars, as the SPE features predict. However, in Kirghiz (Hebert & Poppe 1963), uvulars are said to alternate with velars as a function of vowel backness, not vowel height. Thus in Kirghiz uvulars seem to be treated as being backer, not lower, than velars: Eskimo and Kirghiz reify the phonetic diagonal line differently[3]. Another puzzling case is that of !Xoo (Traill 1985). X-rays show that !Xoo uvulars differ from velars phonetically not in height but in backness, yet phonological rules in the language treat both as [+back], along with [+back] vowels.

Another problem involves characterizing pharyngeal and laryngeal consonants. K&K express some reservations about whether an Arabic rule lowering /i/ to /ɑ/ in a pharyngeal environment supports the use of [low] for pharyngeal consonants, since laryngeal consonants are also involved in the rule. SPE describes laryngeal consonants as [+low] to handle such patterning, but clearly this is not a low tongue body articulation. A related complication is that the feature combination [+low,+back] in practice overlaps with the vowel harmony feature [ATR] (or [expanded pharynx]), in that both may involve movement of the tongue root in the lower pharynx. If features are really meant to correspond to articulators, then this duplication should be unnecessary.

Finally, it is important to note that in SPE, [high] replaced the Jakobson, Fant & Halle feature [diffuse] so as to correctly group together certain consonants and vowels: Hyman (1975) gives a good review of this point, plus others concerning the differences between the two feature systems.

2. Secondary articulations. The same tongue body features that are used for vowels and primary consonant articulations are also used for secondary articulations in which vowel qualities are superimposed on consonants. Thus a palatalized labial not only has all of the features associated with its labial articulation, but also the features associated with palatalization: the tongue body is [+high,-low,-back]. This is a very direct representation of the idea that secondary articulations involve the simultaneous addition of vowel articulations to other, primary, consonant articulations.

a. Primary vs. secondary. In this system, secondary articulations are represented with the same features as primary consonant articulations involving the tongue body. This means that it is not possible to represent secondary articulations on consonants whose primary articulations are made with the tongue body. Now whether this is desirable must be a phonetic

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[3]This assumes that the description of Kirghiz is phonetically accurate; if uvulars really alternate with <u>palatals</u> then of course there is no problem for the SPE features. Also, it should be noted that even if the facts are as given, it is still possible to represent the consonant alternation with SPE features, if the features [high] and [back] are unspecified. However, such a derivation will not express the apparent phonetic generalization.

issue, since many languages are considered to have secondary articulations at such places of articulation phonologically, corresponding to secondary articulations at other places of articulation. For example, some Slavic languages have "palatalized velars" along with palatalized labials and coronals; Maddieson (1984) gives several other languages with such segments. However, under the SPE hypothesis, there can be no phonetic difference between a palatalized velar and a palatal: when the specification for palatalization ([-back, +high, -low]) is applied to primary velars ([+back, +high, -low]), a primary palatal results. If a language has sounds which pattern within the phonology as palatalized velars, they should be phonetic palatals. Chomsky & Halle simply assert that this is so, without citing any evidence.

In Keating (in preparation) I consider this claim in some detail. Use of the UCLA X-ray database (in this issue of WPP) shows that indeed palatalized velars have occlusions that are entirely fronted relative to plain velars. However, palatalized velars do not look like palatals; palatals, but not palatalized velars, involve a coronal articulation with very broad contact in the post-alveolar region. Palatalized velars look like velars that have been fronted along the palate, without contact being broader; indeed, they look like velars in front vowel contexts in languages without palatalization contrasts. However, since palatals are recognized as coronals, the feature system can easily accomodate a distinction between palatals and palatalized velars; the latter are [-coronal].

Palatalized velars are not the only secondary articulation relevant to the SPE claim. Maddieson (1984) lists other cases such as pharyngealized velars in Shilha. Colarusso (1975) and Catford (1977) describe other supposedly impossible sounds, namely palatalized uvular stops and fricatives and pharyngealized uvular fricatives in Ubykh, Abkhaz, and other languages of the NW Causcasus. Ubykh has many back consonants: in addition to palatalized and labialized velar stops and fricatives, it contrasts palatalized, plain, pharyngealized, labialized, and pharyngealized-labialized uvular stops and fricatives. Chomsky & Halle (p. 305) choose to interpret these segments as having primary articulations: the palatalized velars are given as palatals, the palatalized uvulars as velars, and the pharyngealized uvulars as pharyngeals. This results in a proposed straightforward inventory of plain palatals, and plain vs. labialized velars, uvulars, and pharyngeals. It is certainly interesting that the inventory has precisely the gaps allowing such a reanalysis, but Colarusso makes it clear that Ubykh and Circassian languages do indeed lack sounds that occur in other Caucasian languages.

Furthermore, the inventory of the Bzyb dialect of Abkhaz does not allow such easy reinterpretation: here there are what Catford and Colarusso describe as pharyngealized uvular fricatives contrasting with both plain uvulars and plain pharyngeals. Catford (1983) provides two sample X-rays from Bgažba (1964) of these pharyngealized uvulars, though not of plain uvulars or pharyngeals. Colarusso (1977) reproduces more of Bgaãba's X-rays, including the plain and and pharyngealized uvulars. These novel segment types involve very broad constrictions in both the uvular region and the upper pharynx that are unlike the constrictions of primary back consonants.

Catford clearly considers the SPE treatment of secondary articulations to be incorrect. He, like Anderson (1974), describes palatalized velars, palatalized uvulars, and pharyngealized uvulars as having constrictions that are more extensive -- more <u>distributed</u> in the SPE terminology -- than plain velars or uvulars (and presumably palatals). Although this is not true of plain vs. palatalized velars, there is no feature problem with this distinction, as discussed above. Colarusso discusses various options for the other segment types of Bzyb, including [distributed] and [ATR] (see below), deciding in favor of the latter. Clearly, these unusual segment types should be incorporated into any account of feature representations of secondary articulations.

b. Other considerations. An additional problem with the SPE system is that some restrictions on secondary articulations are not captured by this system. Pharyngealization and uvularization are at best rare[4]; languages prefer secondary articulations involving [+high] articulations. Furthermore, not only are secondary articulations involving [+back] rare overall, but no language contrasts any two of them: languages have velarization <u>or</u> pharyngealization[5]. This gap is particularly odd since in vowel systems languages prefer height to backness contrasts. The SPE system for describing secondary articulations, by treating them all as equivalent to vowel contrasts, does not predict such a difference.

It is also interesting that in Maddieson (1984) no retroflex, palatal, palatoalveolar, or labial-velar stops have <u>any</u> secondary articulations. (However, labialized palatoalveolar and labialized palatal <u>fricatives</u> and <u>affricates</u> occur.) Presumably this is in part because these categories of plosives, and secondary articulations, are all rare, making their combination statistically unlikely.

Thus there are some problems with representing secondary articulations by vowel features. A different point that is often raised in this regard seems less problematic, however. At a phonetic level of description, it is clear that vowels and back consonants can all be somewhat pharyngealized in the context of contrastively pharyngealized segments (e.g. Ghazeli 1977, Catford 1977). This fact is sometimes taken to show that vowel features cannot be used for both kinds of segments (e.g. Hyman 1975:50), since this would require back vowels to be further backed by assimilation. However, such contextual effects show only that underlying vowel quality and the assimilation cannot both use a single binary vowel feature value. This suggests at least two (not incompatible) solutions to the problem: underspecification of underlying vowel quality, and phonetic (i.e. non-

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[4]What is described as pharyngealization in Arabic varies phonetically across dialects from velarization to uvularization to true pharyngealization, with Tunisian clearly having uvularization (Ghazeli 1977), and Syrian, Jordanian, and related dialects supposedly more likely to have true pharyngealization.

[5]A possible exception suggested by Ian Maddieson is certain Ethiopian languages not listed in UPSID that may contrast labial-velarization with pharyngealization. However, the velarization might then be redundant.

binary) feature values in assimilation. For the latter approach, see Keating (1987).

c. Redundant vowel features. An issue related to secondary articulations is the assignment of redundant tongue body features to coronal consonants. When no secondary articulation occurs with a consonant, it may have certain expected or redundant values for tongue body features. For labials, it is impossible to say what the tongue should be doing except on the basis of the surrounding context. But for coronals, certain articulations may be expected for ease in positioning the tongue blade. In SPE (pp. 306-7) it was assumed that the anterior consonants and the coronals, in the absence of language-particular phonological values, were all [-back] redundantly. Furthermore, the palatoalveolars were also [+high]. This combination of [-back] and [+high] for palatoalveolars means that they should be (non-distinctively) palatalized in, for example, English. This is not accurate phonetically, though arbitrary phonetic implementation rules could produce the appropriate results. Nonetheless, it seems preferable not to specify tongue body positions so completely in these cases.

More recently Stevens, Keyser, & Kawasaki (1986) have proposed that the tongue body feature [back] can redundantly characterize dentals and alveolars, and that this redundant value is capable of playing a phonological role in a language. The value for [back] agrees with the usual value for [distributed], namely, dentals [+back] and alveolars [-back]. Stevens et al. argue for redundant values of [back] in part because in some Australian languages such as Lardil, vowels alternate in backness after stem-final consonants that differ in distributedness. Thus in their analysis, not only must the features have these redundant values, but those values must be available within the phonology, as in the SPE theory. Alternatively, the anterior consonants could perhaps be distinguished as [+back] vs. [-back] all along, though [distributed] is still needed to distinguish the [-anterior] coronals. Stevens et al. also claim to find support for these redundant values of [back] in second formant frequency variation in English: F2 onset is lower after dentals than after alveolars, indicating a difference in tongue backness. However, more vowels, with different second formants of their own, would have to be examined to confirm such a result.

3. A single set of features. We have reviewed the use of vowel features for primary consonant places of articulation, contrastive secondary articulations, and redundant tongue body control. Should one set of tongue body features really do all these jobs? SPE (p. 305-8) justified this approach with the following reasons: first, secondary articulations on consonants are clearly related to vowels, both in terms of articulation and in terms of assimilation processes; second, these secondary articulations are mutually exclusive with each other and with primary palatal and dorsal places; third, these primary places may correspond phonologically to secondary articulations at other places in a language (for example, palatals may pattern in a language as palatalized velars, parallel to palatalized labials, etc.). The first reason is the least controversial, since it is simply the traditional view of secondary articulations. It also accounts for part of the second reason, the fact that consonants cannot have more

than one secondary articulation at a time, since vowels cannot occur simultaneously. As for the rest of the second reason, we have already seen that dorsal and palatal consonants can also have phonetically distinct secondary articulations. The third reason is a version of the second.

The intuition underlying the SPE position is that a single articulator, the tongue body, is responsible both for vowels and for certain primary consonant places of articulation, namely palatal and dorsal, and that it can only do one thing at a time. As a consequence of using the same articulator, the primary articulations for these places are strongly affected by the vowel context. Such contextual effects appear to be stronger for these places than for other places, and this difference is evidence for the articulatory relation between palatal and dorsal places, and vowels[6].

D. Labial-velars

Traditionally-based feature systems such as Ladefoged (1971) usually treat labial-velars (and by implication, labial-alveolars) as additional values for a continuous or multi-valued "place of articulation" feature. There is thus no direct representation of the fact that, for example, labial-velars combine labial and velar articulations. (More precisely, for Ladefoged labial-velars would have the value "labial-velar" for the multi-valued [place of articulation] feature, and additionally would have the cover feature representation [+labial]; the labial connection would thus be represented, but not the velar connection.) In the SPE system labial-velars are related more directly to the labial and velar places, but only because they have to be either labialized velars or velarized labials. This ambiguity was taken to be a virtue, and defended as such by Anderson (1976, 1981). However, Ohala (1979, Ohala and Lorentz 1977) has argued persuasively that such ambiguity should not be a variable across languages, but rather available within each language: labial-velars are both labials and velars. They most often behave like velars for nasal assimilation (where the back cavity is more important), but as labials for assimilation of fricatives or spirantization (where the front cavity is more important).

Halle (1983) proposed to represent labial-velars as [+labial, +high, +back], that is, simultaneous independent articulations. He argued that the SPE system distinguishes labial, coronal, and tongue body articulations as

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[6]For all places of articulation, vowel context affects the tongue body position (cf. figures in Perkell 1969). If anything, these tongue body effects are stronger for labials and coronals than for dorsals. Thus the statements above explicitly refer to the primary articulation (the area of constriction) of a place of articulation. The effects of tongue body position are much more noticeable acoustically in dorsal consonants, even though they are articulatorily more limited, because consonant noise, as in frication and stop bursts, is determined mainly by the cavity in front of the constriction. For labials and alveolars (etc.), the tongue body position does not affect this front cavity. For palatals and velars, etc., it does.

independent mechanisms, and thus allows double articulations that combine these (indeed, triple articulations). He contrasts this with traditional place of articulation theory, which would appear to make any arbitrary combination formally possible. This kind of representation for double articulations is pursued further in Sagey (1986) and is discussed by Ladefoged & Maddieson (1986).

II. Vowel features

A. Height and backness

The SPE features for vowels distinguish three primary heights and back vs. front. Other distinctions that might be described along these primary dimensions are instead ascribed in SPE to other features: [tense] and [covered] replacing more height distinctions, and [round] replacing more backness distinctions. The need to distinguish at least four (phonetic) heights and possibly three degrees of backness in lexical representations, is brought up again and again in discussions of vowel features (e.g. Wang 1968, Lindau 1978). In SPE, if a language has more than two vowels within one of the six combinations of binary height and backness features, then those two vowels will have to be distinguished by some non-height feature. The phonological claims, then, are that first, such vowel pairs are more closely related than other pairs, and second, whatever feature is used to distinguish within such vowel pairs will also describe a natural class cutting across vowel heights. For example, the two pairs of mid vowels in a symmetrical seven-vowel system, as in Yoruba, would have to be distinguished by some feature besides [high,low,back]. This new feature defines new natural classes within the language. Such vowel pairs sharing a phonological height are often reflexes of earlier harmony sets (as in Yoruba), or length distinctions (as in Germanic), and so in fact generally do pattern together. The crucial point is that the mere fact that a language has a particular inventory of vowel heights is not in itself evidence against the phonological use of binary height features. Rather, such evidence would have to consist of, e.g. a language with four heights in which no two patterned together as a pair, so that no additional feature could be motivated, or a language in which phonological rules referred to an apparent continuum of height values. While vowel chain shift rules can be expressed with SPE features, they may miss obvious generalizations. For an inconclusive debate over a possible case of this sort, see Lindau (1978) and Yip (1980).

B. [tense] and [ATR]

After SPE, various proposals surfaced to collapse [tense] (as in English and German) with [covered] or [Advanced Tongue Root] (as in West African vowel harmony systems), including Halle & Stevens (1969), Perkell (1971), and Ladefoged (1971); K&K adopt this idea. But Lindau (1978, 1979) argues that phonetically distinct dimensions are involved: in terms of the vocal tract shape, the "tense" distinction is one of tongue height, while the "ATR" distinction is one of total pharynx size, which Lindau renames [expanded/constricted pharynx] to clarify that multiple articulators are involved. According to Lindau, in Agwagwune, a Lower Cross River language of southeastern Nigeria, not only is there ATR harmony, but also there is reduction (laxing) of every vowel in closed syllables. That is, at least for phonetic descriptions, [ATR] must be kept distinct from [tense]. Lindau also suggests the name [peripheral] for [tense] since [tense] is so unclear in meaning; this is fine as long as [peripheral] is understood to include a duration difference, as well as the tongue position difference.

At the same time (Perkell 1971) there was a short-lived move to replace the tongue-body feature [low] with the features [ATR] and [Constricted Pharynx]; these features are used to give an extra vowel height by, for example, Mascaro (1976). Colarusso (1975) also uses these features.

C. [round]

The need for a feature [round] remains uncontroversial, but there is more than one kind of rounding that needs to be represented. Lip action that narrows the area of lip opening can be protrusive or not. Such a phonetic distinction is motivated in Linker (1982)'s cross-language study of vowel rounding. Lindau (1978) adds a feature [compressed] to distinguish the contrastive "inrounding" and "outrounding" of the Swedish high front vowels. Such an additional feature is not needed once a feature [labial] is recognized, though. If [labial], as a kind of cover feature, refers to any involvement of the lips, and [round] is limited to actual protrusion, then non-protrusive rounding can be represented as [+labial] but [-round]. It should be noted that this proposal is different from (in fact, almost the opposite of) one in Anderson (1974).

III. Manner features

A. Major class features

The original major class features in SPE were vocalic, consonantal, and sonorant. However, in Ch. 8 (p. 354) of SPE, [vocalic] was replaced by [syllabic]. Subsequently, [syllabic] was eliminated as a feature, and is now encoded in syllable structure. Thus [consonantal] and [sonorant] are left as the only major class features. The feature [consonantal] distinguishes vowels and the glides [h,?,y,w] from all other consonants. The feature [sonorant] distinguishes vowels and sonorant consonants from obstruent consonants. K&K express some doubts about whether the class of glides should include the non-traditional [h] and [?], but they also give examples justifying all these divisions. The SPE major class features together divide segments into classes of varying sonority. However, some phonologists have proposed using directly a single sonority hierarchy or continuum, as a constraint on syllable structure as well as in certain rules (Hankamer & Aissen 1974, Kiparsky 1979, Steriade 1982, Selkirk 1984).

B. Consonant articulations

Very few changes have occurred with features describing consonant manner of articulation, with the major exception of laryngeal features, which are discussed separately below. Those manner features which are primarily used to distinguish places of articulation, including [strident], were discussed above in (Ib). The definitions and use of such features as [nasal], [lateral], and [continuant] are much as in SPE; any of the earlier texts can be consulted for summaries and discussions of these features.

However, two manner features from SPE, [delayed primary release] and [delayed secondary release], no longer are in general use. The job of these release features, representing the complex nature of affricates and affricated clicks, is now done by contour segment representations in CV phonology. CV theory allows more than one segment matrix to be sequenced within a single segment, eliminating the need for features of timing relations. Later features in the spirit of SPE that are no longer needed for this same reason include [prenasalized] and [preaspirated]. Further implications of such enriched phonological structures are discussed below in (IV).

C. Laryngeal and related features

As Sommerstein (1977) notes, the SPE proposal for voicing (the features [voice], [tense], [heightened subglottal pressure], and [glottal constriction]) was never widely accepted. The feature [glottal constriction] played a marginal, optional role for voicing; the feature [tense] described supralaryngeal adjustments for consonants that would suppress voicing, [heightened subglottal pressure] indicated extra energy for aspiration, and [voice] indicated a particular vocal cord configuration suitable for voicing, not vocal cord vibration per se. Perhaps their most important innovation in this respect was the decision to represent the glottal configuration but not the results of the configuration -- i.e. not whether vocal cord vibration actually occurs. The various features interacted in somewhat complicated ways in determining vibration, aspiration, etc., and were therefore perhaps too hard to learn to use, rather than theoretically unacceptable; there was also little evidence presented in their support.

Among phonologists, the most successful replacements have been the Halle & Stevens (1971) features. (The original paper has not been published, but see e.g. Anderson 1974, 1978, Stevens & Perkell 1977 for descriptions.) Halle & Stevens use four binary features to describe two dimensions of laryngeal control; one is the stiffness/slackness of the vocal cords, the other their spread/constricted positioning. These features, like the SPE features, describe the state and position of the vocal cords at the moment of release in a segment, rather than any resulting activity such as vocal cord vibration or aspiration. They were meant to describe all aspects of laryngeal distinctions, including airstream mechanisms, phonation types, and fundamental frequency, as well as voicing and aspiration. The features attempted to relate all of these dimensions by representing them with shared features. It is clear from Sagey (1986) that they remain in favor with at least some phonologists for all of these uses. However, since the original proposal, many criticisms of these features have been made (several of which are contained in chapters of the Fromkin (1978) tone volume), both in terms of their physical phonetic accuracy, and their phonological usefulness. Some of these will be repeated here.

1. Voicing. First consider the Halle & Stevens (H&S) features simply as a way of representing voicing distinctions. They do not offer a

straightforward characterization in terms of whether or not the vocal cords are vibrating, even though they require a fairly precise physical description of the glottal state. Although Hayes (1984) suggests that some facts from Russian require this type of glottal representation, this move has not been generally endorsed. Such authors as Anderson (1974), Clements (1985), and even Stevens et al. (1986) include a separate [voice] feature, a cover feature to refer either to something like the presence or absence of vocal cord vibration, or to more abstract phonological categories.

Among phoneticians, the H&S features have not been widely adopted, perhaps in small part because most phoneticians had already adopted the "Voice Onset Time" framework of Lisker & Abramson (1964). Thus Lisker & Abramson (1971), Ladefoged (1971), and Keating (1984) all use some version of VOT rather than the static glottal configuration features for phonetic voicing variation (though Keating also uses [voice] as a binary phonological feature). But most importantly, claims made by H&S about vocal cord control for voicing have not been supported by experimental evidence. The H&S feature system assumes that voiced obstruents have slackened vocal cords to allow vibration, while voiceless obstruents have stiffened vocal cords to suppress it. However, Chen (1970) and Hirose and his colleages (cited by Hombert et al. 1979) have provided evidence from laryngeal EMG that there is _no_ difference in vocal cord stiffness for voiced vs. voiceless consonants.

It should be noted that H&S's claims are based on vocal cord modeling rather than observation of speakers. While it is certainly true that, for example, stiffening the vocal cords will prevent voicing, it does not follow that that is how people usually do make voiceless consonants. In the case of voiceless consonants, a glottal spreading gesture is more typically used. The H&S glottal spreading feature, which by definition refers only to the moment of release, necessarily entails aspiration as well as voicelessness. This is because an open glottis at the time of release results in aspiration. Yet voiceless _un_aspirated consonants can also be produced with a glottal spreading gesture: the gesture is simply completed within time of the consonant constriction, so that the glottis is closed by the release. The H&S features cannot distinguish different glottal gesture timing possibilities. They must use the vocal cord stiffness feature to indicate voicelessness without aspiration, but this is done at the expense of descriptive accuracy. (For an account of voicelessness and aspiration which uses only a glottal spreading gesture with different relative timings, see Browman & Goldstein 1986. This limited treatment, however, encounters its own empirical difficulties.)

The other H&S features [±spread glottis], [±constricted glottis] provide three degrees of glottal constriction (spread, neutral, constricted), as opposed to the many degrees used by Ladefoged or Catford. These two features have been widely adopted for the description of aspiration and glottalization, since there is a convenient feature value for each of these characteristics: [+spread glottis] for aspiration and [ḥ], and [+constricted glottis] for glottal stops and glottalization. There is no doubt that the glottis is spread at consonant release for aspiration and constricted for glottalization, and thus these feature values, taken apart from the system as a whole, are phonetically quite accurate. It is probably fair to say that many people use these two particular feature values as names for these characteristics without necessarily endorsing the whole system of four features.

2. Co-occurrences with tone. The features have most often been criticized for their claims about the relations between tone and other dimensions. The four features are used to describe a variety of laryngeal dimensions so as to predict when values along these dimensions will be correlated. Thus, for example, Halle & Stevens view the relation between consonant voicing and tone as a basis for their feature system. The appeal of the features lies in such correlations, which indeed are often observed in languages. We will consider each in turn, leaving the question of airstream mechanisms until the end.

a. Tones and voicing. The basic idea is that stiff vocal cords raise f0 on a sonorant while slack vocal cords lower it; thus Low tone is represented by the combination [-stiff, +slack], Mid tone by [-stiff, -slack], and High tone by [+stiff, -slack]. Since slack vocal cords also facilitate voicing in obstruents, such voicing is associated with Low tone or lowered f0 in an adjacent sonorant. Since stiff vocal cords also suppress voicing, voicelessness is associated with High tone or raised f0 in an adjacent sonorant. Since the vocal cords for voiced sonorants have neutral tension, they are associated with Mid tone, or no special pitch perturbation effects. Such correlations are indeed observed in languages, but not as uniformly as the hypothesis requires. One problem with this system is that in fact sonorants often affect f0, and tones, just as obstruents do. This is especially obvious when the sonorants come in voiced/voiceless pairs (Maddieson 1984). Another point is made by Traill et al. (ms) with respect to the "depressor" consonants of Zulu. Here, where non-tonal effects of consonants on vowel f0 have been phonologized, they are not correlated with phonetic voicing. Other problems along these lines are discussed by Anderson (1978:161-167) and Hombert (1978).

b. Tones and other consonant dimensions. A further set of correlations with tone arises because vocal cord stiffness is also involved in describing phonation types and airstream mechanisms. Slack vocal cords not only imply Low tone and obstruent voicing; they also are used for breathy voice. Neutral vocal cords not only imply Mid tone and sonorant voicing; they also are used for implosives and two kinds of voiceless obstruents. Stiff vocal cords not only imply High tone and voicelessness; they also are used for ejectives and voiceless glottalized obstruents. In qualitative phonetic terms, f0 differences of these kinds often are observed with these consonant types (though see Painter 1978's data for some counterexamples). One counterexample, even to these qualitative predictions, given by Hombert (1978) is that ejectives, unlike other glottalized consonants, are neutral with respect to tone. Other difficulties arise because the feature system does not confine itself to general qualitative predictions about "higher" and "lower" f0. Because it represents three different pitch levels, it makes much stronger, more specific claims that can run into empirical difficulty. For example, both plain voiced and breathy voiced consonants are predicted to lower tones and f0; they do, but in fact breathy voicing lowers f0 more than plain voicing.

A further objection in the literature is that these glottal correlations are singled out for featural representation while other articulatory effects on f0 have no representation in the H&S system. The H&S features do not represent, for example, the effects of vowel height, vertical larynx movement, or aerodynamics on f0, yet there are no other formal mechanisms for f0 variation. For discussion and/or examples, see Hombert (1978), Anderson (1978), Bird (1971), Painter (1978).

c. Tones and phonation type. Vowels themselves may vary in phonation type, and in the H&S system this should preclude orthogonal tone specifications. The H&S features predict the following correlations of phonation and tone: first, a plain vowel may have any of the three tones; second, breathy and creaky vowels, (as well as voiced consonants) go with Low tone; third, (plain) glides (and, vacuously, voiceless vowels) go with Mid tone; finally, glottalized vowels go with High tone. However, in languages, various phonation types may occur with many different tones; for some examples of a single phonation type contrasting in tone, see Anderson (1978), Ladefoged (1983) and Maddieson & Ladefoged (1985).

This class of co-occurrences is important, because here it is the same segment (the vowel) that carries both the tone and the phonation type. In the cases above, where the vowel has the tone and the consonant has the voicing or other dimension, it is possible at least to represent mis-matched co-occurrences; the claim would be only that such mismatches should be marked. Here, however, contradictory values of the H&S features need to appear on a single segment.

3. Airstream mechanism features. Airstream mechanisms refer to the source and direction of airflow for speech sounds. While most speech sounds involve a pulmonic egressive mechanism, others are also possible, most notably glottalic egressive (ejective), glottalic ingressive (implosive), and velaric ingressive (click). For descriptions of these mechanisms, see Ladefoged (1971, 1982). SPE proposed several tentative features for airstream mechanisms, which are discussed by Ladefoged (1971). The SPE features are basically just the traditional descriptive terms: [ejection], [implosion], [velaric suction], [velaric pressure]. Though Ladefoged has his own proposals on this topic, certainly the SPE features will do the job.

However, the H&S laryngeal features also distinguish categories of consonants produced with different airstream mechanisms. Therefore H&S suggested, but did not insist, that just the laryngeal features would suffice. These features do not directly encode the airstream mechanisms, but in representing laryngeal configurations, do succeed in capturing the minimal contrasts involved. This step is argued for by Sagey (1986), who uses only the Halle & Stevens laryngeal features. Two issues arise in connection with this move. One is the success of predictions about the interaction of airstream mechanisms with other laryngeal dimensions; this was discussed in the preceding section (2b). The other is the role of redundant information in the feature system: the argument here is that airstream mechanism per se is a redundant detail that can be filled in by phonetic rules. Yet it is not the case that the H&S features in general aim to eliminate redundancy; glottal articulatory distinctions, not phonological ones, are the basis of the system. While no airstream difference is noted between glottalized and ejective voiceless consonants (which form a single category here), voiced laryngealized consonants are distinguished from implosives, though they never contrast in languages. More strikingly, voicelessness in vowels is distinguished from voicelessness in approximants. The H&S features are clearly designed to represent phonetic detail, not to eliminate it. This makes the appeal to redundancy in the single case of airstream mechanisms a weak argument.

In sum, there are enough problems with the H&S feature system that it should be used only with extreme caution and only after considering the difficulties discussed here and in the literature.

IV. Prosodic features

The most profound changes in features since SPE involve the prosodic features. Post-SPE developments in phonological theory have added multi-level structure to phonological representations, and as a result certain segmental features are no longer needed. Thus the total number of features is reduced under the new theories. The features [stress] and [syllabic] are now encoded in structure. These features share the property of being relational rather than intrinsic to segments. Thus [stress] is no longer a feature assigned to individual segments (typically, with vowels receiving [+stress]), but is now a relational property of syllables in strong-weak relations encoded in metrical structure (e.g. Hayes 1981). Similarly, as mentioned above, [syllabic] is now encoded in hierarchical tree structure built over segments (e.g. Kiparsky 1979, Clements & Keyser 1983). For both features, the exact nature of the structure posited differs across particular proposals, but the general effect of the research on features seems agreed upon. This change means that it is no longer necessary to define phonetic correlates of a feature [syllabic].

As part of CV phonology (McCarthy 1979, 1981; Halle & Vergnaud 1980; Steriade 1982, and many subsequent works), features encoding timing relations, including [length], are also recast as structure. This change also affects timing features discussed earlier in (IIIb), such as [delayed primary release], [prenasalized], [preaspirated], and other similar features. After SPE, various phonologists proposed complex segment representations to deal with sequences of feature values within a single segment (e.g. Campbell 1974, Anderson 1976, Williamson 1977). In CV theory these features are replaced by sequences of skeletal positions and sequences of featural melodies (matrices). The two sequences are linked together, sometimes in two-to-one fashion. Gemination is represented not by a feature [length] on a segment, but as a single melody linked to two skeletal positions; "contour" segments such as unit affricates and prenasalized stops are represented as two melodies linked to a single skeletal position. With [length] eliminated as a feature, it is not available for other possible uses, e.g. distinguishing taps from trills. However, Anderson (1974) proposed that, even if gemination is represented by structure rather than a feature, a phonetic feature [n long] should be retained for non-contrastive differences of durational detail.

V. Conclusion

On the basis of this review, we can identify some recent trends affecting feature inventories. An important development is that some features have been replaced with structure. The eliminated features represented relative properties of segments that are now encoded in metrical or CV structure. The role of features is now more limited to inherent phonetic properties of segments. The development of feature geometry extends this trend further: representing natural classes is now done by hierarchical structure as well as by the features themselves.

Another trend since SPE has been to eliminate predictable phonetic detail from feature representations. This has resulted in the elimination of a few features. However, eliminating redundancy is done at a price: it becomes more difficult to relate phonological representations to phonetic ones. Doing so requires that phonetic features be added into full phonetic representations, a move that under the SPE system was claimed to be unnecessary. However, a current contrary trend is the interpretation of feature organization in terms of articulation, that is, feature organization may be based on articulatory organization. Such a phonetic basis for feature representations is in the spirit of SPE, but does not itself contribute to deriving explicitly phonetic surface forms.

Despite these and other changes in feature inventories, many features have remained fairly stable over the years. Some features are used by nearly everyone working within a generative framework; relatively few features are embroiled in controversy. It is quite possible to choose a reasonable set of features to work with; in problem areas one can retreat to more traditional features. In this spirit I offer a concensus set of features. While it does not address every question or need, it avoids the worst empirical and theoretical difficulties, and in most respects represents current practice.

Concensus set of segmental features:

consonantal, sonorant, nasal
anterior, labial
coronal, strident, distributed
lateral, continuant
high, low, back, round, tense, ATR
voiced
spread glottis (aspirated), constricted glottis (glottalized)
implosive, ejective, click
tonal features

VI. Addendum: Summary of SPE Features

Here is a convenient summary of the complete set of features proposed in SPE, in terms of their current status. As additional reference points, for each feature it is noted whether it appears in Stevens et al. (1986) and/or Sagey (1986), where these two sources are taken to reflect the recent views of Stevens and Halle, respectively. (The features in Sagey (1986) are much the same as those in Halle & Clements (1983)). The definitions of features are discussed in the text above.

[vocalic] - even in SPE, replaced by [syllabic]
[consonantal] - no changes; see K&K;
    in Stevens et al, Sagey
[syllabic] - replaced by CV syllable structure; see Clements & Keyser
[sonorant] - as binary feature, no changes; some prefer sonority hierarchy;
    see K&K;
    in Stevens et al., Sagey
[nasal] - no changes;
    in Stevens et al., Sagey

[lateral] - no changes;
    in Stevens et al, Sagey
[continuant] - no changes;
    in Stevens et al., Sagey
[strident] - redefined in Halle & Stevens 1979;
    in Stevens et al., Sagey

[coronal] - redefined in Halle & Stevens 1979, also Lahiri & Blumstein 1984;
    in Stevens et al., Sagey
[anterior] - K&K found suspicious; possibly limited to coronals;
    in Stevens et al., Sagey
[distributed] - doing more work in Halle & Stevens 1979; possibly limited to
    coronals;
    in Stevens et al., Sagey

[delayed (primary) release] - replaced by CV structure

[high] - as binary feature, no changes; some prefer continuous scale;
    some discussion of use for primary consonant places;
    in Stevens et al., Sagey
[low] - as for [high];
    in Stevens et al., Sagey
[back] - as for [high]; in Stevens et al., Sagey
[round] - supplemented with cover feature [labial];
    in Stevens et al., Sagey
[tense] - rarely used for obstruent distinctions, usually limited to
    vowel distinctions; not same as [covered] per Lindau 1979;
    in Stevens et al.
[voice] - mainly used as cover feature for actual voicing, not glottal
    state for spontaneous voicing;
    in Stevens et al.

[covered] - usually called [ATR]; more accurately, [expanded] (Lindau)

[glottal constriction] - replaced by Halle & Stevens 1971 [constr gl]

[delayed secondary release] - rarely discussed; argued by Sagey to never be contrastive
[velaric suction] - as for [delayed secondary release]
[implosion] - replaced by Halle & Stevens 1971 features
[velaric pressure] - as for [delayed secondary release]
[ejection] - replaced by Halle & Stevens 1971 features
[heightened subglottal pressure] - for aspiration, replaced by Halle & Stevens [spread glottis]; not used for stress as stress is no longer segmental; for trill vs tap, replaced by [rate] for Ladefoged

[stress] - replaced by metrical structure
[length] - replaced by CV structure; however, in Stevens et al.

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INDEX OF FEATURES

This is an alphabetic listing of the features discussed in this article. They are listed by section number. It includes actual feature names (in brackets []) and more traditional place terms. SPE means that it is an SPE feature and is mentioned in VI, Addendum.