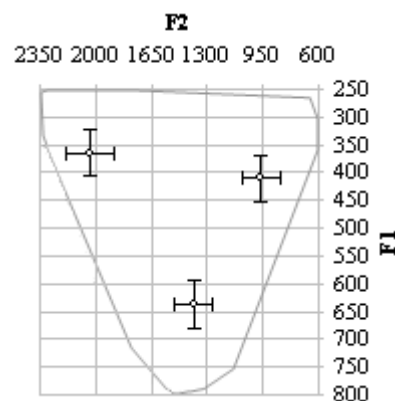


## APPENDIX B

Below are the acoustic geometries for the 17 structural configurations that appear in five or more languages in the corpus. For each configuration, its component vowel categories are listed, with averages and standard deviations of their normalized formant frequencies, including F3 and F2' estimates. For each category, narrow IPA transcription is proposed, based on the average formant frequencies of the category and the proposed F1 and F2 frequencies of IPA transcription symbols in Figure 3-7 in Section 3.6.1. Vowel data are followed by F1 and F2 spans and of the F1x2 area (in 10000Hz<sup>2</sup> units) of the polygon whose angles are all the peripheral vowels. Also listed are all the languages (each followed by its unique ISO 639-3 three-letter code) where the particular structure appears. In case the language appears under other structures, its three-letter code is followed by the serial numbers (from Appendix A) of the entries listed with the current structure. The formant charts display average F1x2 qualities with one standard deviation ranges. Structures appearing in less than five languages in the survey are listed at the end.

### 3S0:

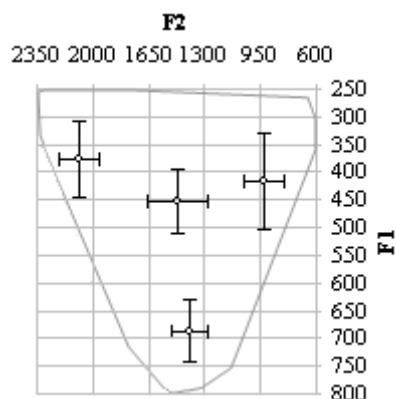
IPA	F1	F2	F3	F2'
<b>ɪ</b>	365 (±42)	2034 (±156)	2727 (±101)	2363 (±264)
<b>ɛ</b>	637 (±42)	1385 (±123)	2463 (±18)	1405 (±147)
<b>ɔ</b>	410 (±42)	959 (±121)		959 (±121)
<b>F1<sub>SPAN</sub></b>	<b>275 (±64)</b>	<b>F2<sub>SPAN</sub></b>	<b>1075 (±234)</b>	<b>Area:</b> 13.52 (±5.52)



**Languages:** Tunisian Arabic (aeb:1), Palestinian Arabic (ajp:1-2), Aleut (ale), Amis (ami), Moroccan Arabic (ary), Egyptian Arabic (arz:1-2), Chickasaw (cic), Dogri (dgo:1), Hausa (hau:1), Hupa (hup), Greenlandic (kal), Molalla (mbe:1), Creek (mus), Punjabi (pan:1), Pashto (pbu:1), Quichua (que), Tachelhit (shi), Totonac (top), Tausug (tsg), Urdu (urd:1)

### 3S1:

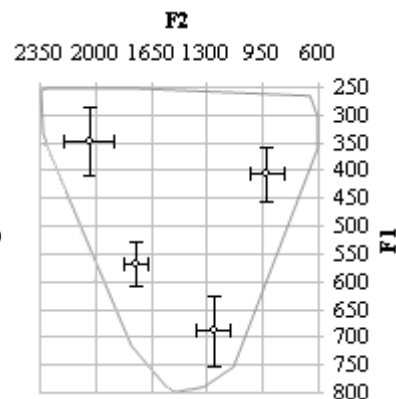
IPA	F1	F2	F3	F2'
ɪ	376 (±68)	2084 (±130)	2751 (±73)	2432(±205)
e	686 (±55)	1395 (±113)	2479 (±31)	1416 (±132)
ø	417 (±86)	925 (±128)		925 (±128)
ə, œ	454 (±58)	1472 (±189)	2421 (±54)	1526 (±229)
<b>F1<sub>SPAN</sub>:</b>	<b>313 (±97)</b>	<b>F2<sub>SPAN</sub>:</b>	<b>1158 (±255)</b>	<b>Area:</b> 16.03 (±5.58)



**Languages:** Northern Qiang (cng), Rukai (dru), Khanty (kca), Dutch (nld:1-2), Paiwan (pwn), Wu (wu:1), Cantonese (yue:1-4)

### 4L0:

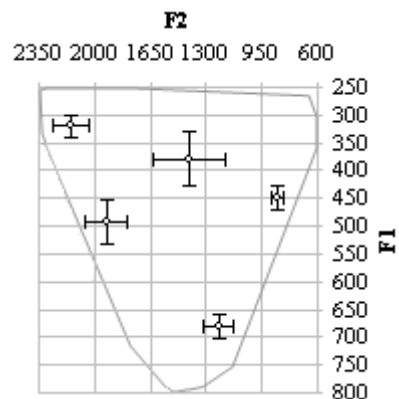
IPA	F1	F2	F3	F2'
ɪ	348 (±61)	2041 (±156)	2745 (±134)	2396 (±298)
ɛ	570 (±40)	1744 (±76)	2507 (±25)	1857 (±99)
ǎ	689 (±63)	1259 (±109)		1259 (±109)
ø	407 (±50)	922 (±103)		922 (±103)
<b>F1<sub>SPAN</sub>:</b>	<b>341 (±120)</b>	<b>F2<sub>SPAN</sub>:</b>	<b>1119 (±258)</b>	<b>Area:</b> 21.42 (±9.98)



**Languages:** Tunisian Arabic (aeb:2-3), Apache (apw), Banawa (bnh), English (eng:9-121), Maltese (mlt), Navajo (nav), Urdu (urd:2)

### 4L1:

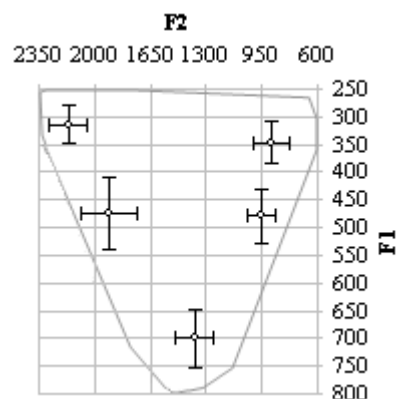
IPA	F1	F2	F3	F2'
ĩ	320 (±19)	2145 (±115)	2826 (±86)	2583 (±211)
ɛ	492 (±41)	1926 (±136)	2601 (±70)	2131 (±199)
ɑ	681 (±21)	1221 (±91)		1221 (±91)
ø	450 (±22)	849 (±38)		849 (±38)
ə, ø	379 (±48)	1405 (±223)	2377 (±84)	1450 (±282)
<b>F1<sub>SPAN</sub>:</b>	<b>360 (±38)</b>	<b>F2<sub>SPAN</sub>:</b>	<b>1296 (±139)</b>	<b>Area:</b> 27.24 (±15.56)



**Languages:** Japanese (jpn:1-11), Karitiana (ktn), Maori (mri), Mundurucu (myu), Dutch (nld:6-7), Sakurabiat (skf), Akuntsu (???)

## 5S0:

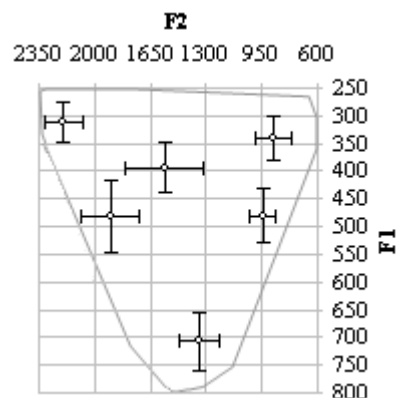
IPA	F1	F2	F3	F2'
ĩ	314 (±35)	2164 (±122)	2849 (±107)	2636 (±253)
ě	474 (±64)	1915 (±177)	2612 (±108)	2130 (±282)
ɸ	699 (±52)	1373 (±124)	2483 (±31)	1389 (±147)
ǒ	479 (±49)	948 (±85)		948 (±85)
ũ	346 (±39)	889 (±117)		889 (±117)
<b>F1<sub>SPAN</sub></b> :	<b>389 (±86)</b>	<b>F2<sub>SPAN</sub></b> :	<b>1289 (±228)</b>	<b>Area:</b> <b>27.39 (±9.60)</b>



**Languages:** Palestinian Arabic (ajp:3-5), Aragonese (arg), Egyptian Arabic (arz:3-4), Toba Batak (bbc), Burarra (bvr), Catalan (cat:1-2), Chontal (chf), Tsez (ddo), Greek (ell), Basque (eus:1-9), Montana Salish (fla), Kunwinjku (gup), Glwi (gwj), Hakka (hak), Hausa (hau:2), Serbo-Croatian (hbs), Hebrew (heb), Hadza (hts), Japanese (jpn:12-13), Kannada (kan), Georgian (kat), Lithuanian (lit:1-4), Lele (lln), Jalapa Mazatec (maj), Musey (mse), Bambassi (myf), Nambikwara (nab), Min Taiwanese (nan), Ndebele (nde), !Xoo (nmn), Piedmontese (pms), Quechua (quz), Sicialian (scn), Slovak (slk:1-2), Slovenian (slv:1), Shona (sna), Spanish (spa), Siswati (ssw), Huehuetla Tepehua (tee), Telugu (tel:1-5), Yiddish (yid), Juchitan Zapotec (zai)

## 5S1:

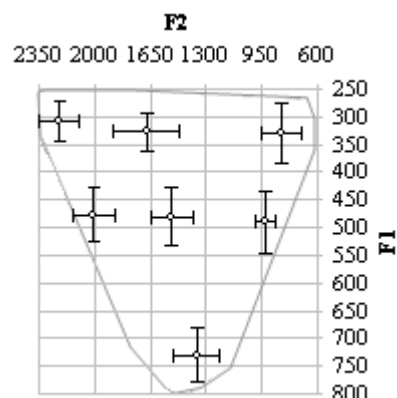
IPA	F1	F2	F3	F2'
ĩ	312 (±32)	2196 (±85)	2870 (±77)	2689 (±180)
ě	481 (±48)	1903 (±169)	2600 (±87)	2107 (±252)
ɸ	707 (±46)	1345 (±149)	2482 (±26)	1361 (±166)
ǒ	481 (±54)	945 (±111)		945 (±111)
ũ	340 (±41)	876 (±94)		876 (±94)
ə, ø	394 (±46)	1561 (±243)	2411 (±89)	1652 (±319)
<b>F1<sub>SPAN</sub></b> :	<b>399 (±73)</b>	<b>F2<sub>SPAN</sub></b> :	<b>1344 (±154)</b>	<b>Area:</b> <b>28.53 (±8.63)</b>



**Languages:** Assyrian Neo-Aramaic (aii), Gheg Albanian (aln), Bodo (brx), Bulgarian (bul), Welsh (cym:1), English (eng:14-15), Basque (eus:10), Paraguayan Guarani (gug), Gumuz (guk), Indonesian (ind), Kera (ker), Kuruaya (kyr), Mawa (mcw), Isthmus Mixe (mir), Moukoulu (moz), Dalabon (ngk), Nias (nia), Angami (njm), Anong (nun), Pashto (pbu:2), Polish (pol), Russian (rus), Sursurunga (sgz), Tajik (tgk), Truku (trv), Tsou (tsu)

### 5S2a:

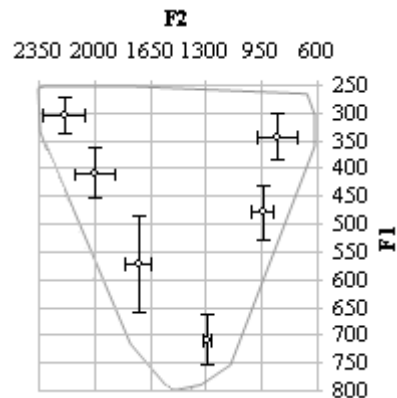
IPA	F1	F2	F3	F2'
ɪ	309 (±36)	2228 (±125)	2902 (±124)	2769 (±289)
ɛ	477 (±48)	2004 (±138)	2650 (±94)	2257 (±224)
a	730 (±49)	1361 (±146)	2521 (±51)	1375 (±172)
ɔ	490 (±57)	925 (±64)		925 (±64)
ʊ	328 (±54)	829 (±125)		829 (±125)
i, y	327 (±35)	1672 (±208)	2381 (±66)	1800 (±277)
ɶ, œ	481 (±52)	1517 (±131)	2413 (±63)	1576 (±164)
<b>F1<sub>SPAN</sub></b> :	432 (±77)	<b>F2<sub>SPAN</sub></b> :	1409 (±239)	<b>Area:</b> 33.95 (±10.59)



**Languages:** Amharic (amh), Tepetotutla Chinantec (cnt), Welsh (cym:2-4), German (deu:1-13), North Frisian (frr:1), Hungarian (hun:1-2), Komi (kpv), Dutch (nld:8-9), Romanian (ron:1), Albanian (shq:1-6), Sundanese (sun), Udmurt (udm), Kurtoep (xkz), Cantonese (yue:5-8)

### 6L0:

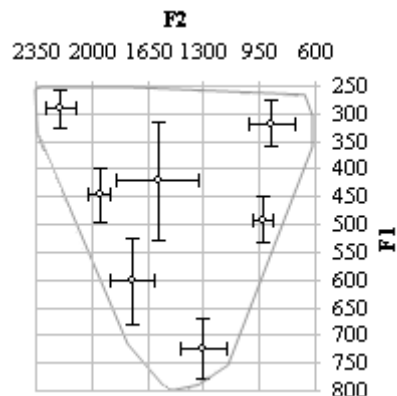
IPA	F1	F2	F3	F2'
ĩ	304 (±33)	2188 (±134)	2876 (±116)	2693 (±286)
e	409 (±45)	1993 (±125)	2671 (±97)	2268 (±221)
ɛ	573 (±86)	1726 (±80)	2510 (±40)	1836 (±122)
ɶ	708 (±46)	1296 (±27)		1296 (±27)
õ	479 (±49)	942 (±71)		942 (±71)
ũ	343 (±41)	855 (±127)		855 (±127)
<b>F1<sub>SPAN</sub></b> :	403 (±79)	<b>F2<sub>SPAN</sub></b> :	1344 (±242)	<b>Area:</b> 29.28 (±7.78)



**Languages:** Catalan (cat:3), Darma (drd), English (eng:16-17), Korean (kor:2), Lithuanian (lit:5-9), Slovak (slk:3-4), Telugu (tel:6-8), Ukrainian (ukr)

### 6L1:

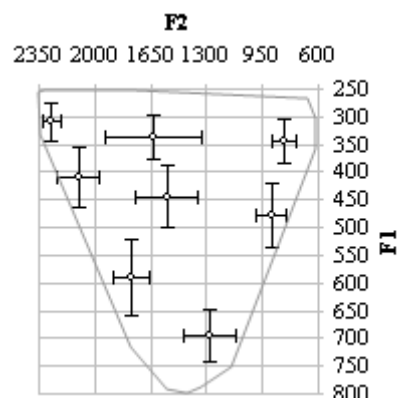
IPA	F1	F2	F3	F2'
ĩ	292 (±36)	2197 (±94)	2890 (±78)	2717 (±188)
ě	447 (±48)	1948 (±69)	2624 (±33)	2175 (±96)
æ	603 (±76)	1742 (±138)	2519 (±54)	1854 (±190)
ɶ	723 (±55)	1301 (±143)		1311 (±156)
õ	492 (±41)	930 (±65)		930 (±65)
ʊ	318 (±42)	872 (±146)		872 (±146)
ɶ, ø	421 (±106)	1585 (±261)	2387 (±64)	1678 (±348)
<b>F1<sub>SPAN</sub></b> :	442 (±71)	<b>F2<sub>SPAN</sub></b> :	1365 (±163)	<b>Area:</b> 34.15 (±7.51)



**Languages:** Babine (bcr), Estonian (ekk:1-2), Gujarati (guj), Dutch (nld:10-12), Occitan (oci), Chichimeca (pei), Albanian (shq:7-8), Wolof (wol:1)

## 6L2:

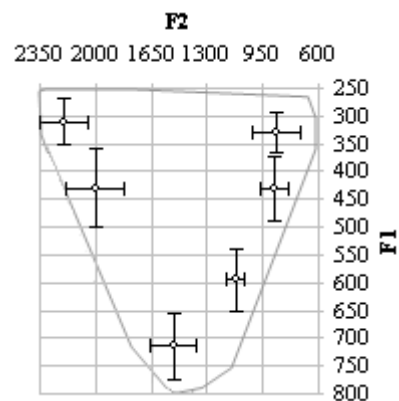
IPA	F1	F2	F3	F2'
ɪ	309 (±34)	2270 (±58)	2931 (±52)	2835 (±120)
e	409 (±54)	2102 (±134)	2741 (±98)	2444 (±232)
ɛ	590 (±68)	1769 (±114)	2523 (±44)	1892 (±163)
ǎ	696 (±47)	1279 (±158)		1287 (±179)
o	478 (±59)	893 (±92)		893 (±92)
u	343 (±39)	816 (±79)		816 (±79)
i, ỹ	336 (±40)	1631 (±305)	2368 (±47)	1755 (±387)
ə, ø	444 (±56)	1547 (±195)	2401 (±74)	1621 (±245)
<b>F1<sub>SPAN</sub></b> : 391 (±68) <b>F2<sub>SPAN</sub></b> : 1478 (±108) <b>Area</b> : 33.34 (±6.51)				



**Languages:** German (deu:14-18), Finnish (fin), North Frisian (frr:2), Icelandic (isl), Korean (kor:3), Livonian (liv), Dutch (nld:13-14), Uyghur (uig), Oriat (xal)

## 6R0:

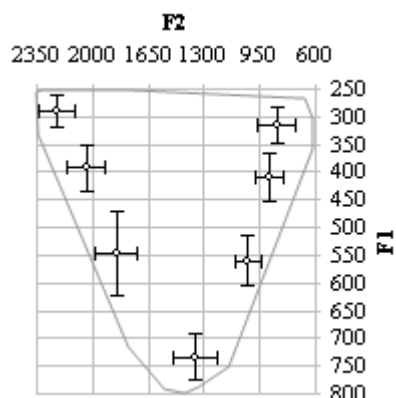
IPA	F1	F2	F3	F2'
ĩ	310 (±43)	2196 (±153)	2881 (±121)	2705 (±299)
ɛ	430 (±70)	2003 (±187)	2679 (±130)	2283 (±314)
ɑ	715 (±59)	1512 (±143)	2503 (±29)	1556 (±176)
ʌ, ɒ	594 (±56)	1122 (±52)		1122 (±52)
o	432 (±58)	877 (±91)		877 (±91)
u	328 (±36)	861 (±151)		861 (±151)
<b>F1<sub>SPAN</sub></b> : 408 (±92) <b>F2<sub>SPAN</sub></b> : 1366 (±265) <b>Area</b> : 31.36 (±7.51)				



**Languages:** Bedjond (bjv), Viri (bvi), Southwestern Dinka (dik:1), English (eng:18-23), Nar (kwv:1), Latvian (lav), Sar (mwm), Mbay (myb), Nepali (nep), Oriya (ori), Persian (pes), Kaba (sbz)

### 7S0:

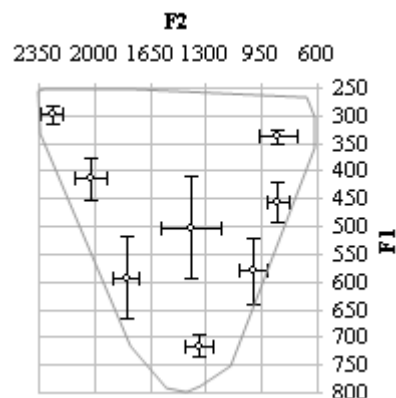
IPA	F1	F2	F3	F2'
i	289 (±29)	2222 (±115)	2915 (±106)	2780 (±266)
e	393 (±41)	2040 (±117)	2709 (±80)	2349 (±197)
ɛ	546 (±75)	1852 (±135)	2563 (±64)	2015 (±196)
a	733 (±40)	1354 (±136)	2499 (±19)	1371 (±148)
ɔ	560 (±46)	1023 (±86)		1023 (±86)
o	410 (±43)	895 (±89)		895 (±89)
u	316 (±33)	843 (±118)		843 (±118)
<b>F1<sub>SPAN</sub></b> : 446 (±68)		<b>F2<sub>SPAN</sub></b> : 1398 (±213)		<b>Area</b> : 35.41 (±10.50)



**Languages:** Defaka (afn), Amuzgo (amu), Oroko (bdu), Bengali (ben), Tuwuli (bov), Dibole (bvz), Catalan (cat:5-9), Dogri (dgo:2), Southern Dinka (dib), Southwestern Dinka (dik:2), Eastern Dinka (dks), Ndumbea (duf), English (eng:24-26), Gban (ggu), Galician (glg), Ife (ife), Italian (ita), Kirikiri (kiy), Mpiemo (mcx), Mbosi Olee (mdw), Burmese (mya), Neapolitan (nap), Low German (nds), Khana (ogo), Punjabi (pan:2), Portuguese (por:1-6), Sele (snw), Sardinian (sro), Setswana (tsn), Urdu (urd:3-4), Venetian (vec), Wolof (wol:2), Gunu (yas), Yoruba (yor:1-3)

### 7S1:

IPA	F1	F2	F3	F2'
i	299 (±15)	2264 (±70)	2934 (±55)	2836 (±137)
e	414 (±38)	2017 (±101)	2679 (±71)	2298 (±168)
ɛ	593 (±74)	1802 (±81)	2533 (±24)	1935 (±118)
ɐ	716 (±20)	1342 (±87)	2495 (±17)	1351 (±100)
ɔ	581 (±61)	1003 (±94)		1003 (±94)
ɒ	455 (±37)	851 (±69)		851 (±69)
ʊ	338 (±13)	847 (±121)		847 (±121)
ə	502 (±92)	1393 (±191)	2424 (±63)	1430 (±229)
<b>F1<sub>SPAN</sub></b> : 418 (±35)		<b>F2<sub>SPAN</sub></b> : 1471 (±149)		<b>Area</b> : 34.59 (±5.24)

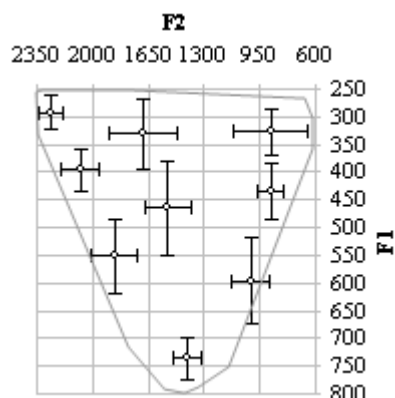


**Languages:** Catalan (cat:10), Eton (eto), Korean (kor:5-6), Maithili (mai:1-3), Portuguese (por:7), Slovenian (slv:2)

## 7S2:

IPA	F1	F2	F3	F2'
i	292 (±31)	2263 (±73)	2940 (±75)	2849 (±172)
e	396 (±37)	2078 (±124)	2730 (±88)	2409 (±210)
ɛ	552 (±66)	1864 (±141)	2565 (±66)	2031 (±208)
a	735 (±38)	1404 (±92)	2502 (±22)	1423 (±109)
ɐ	596 (±78)	1007 (±116)		1007 (±116)
o	434 (±51)	882 (±83)		882 (±83)
u	327 (±41)	881 (±237)		881 (±237)
i,ɨ	330 (±63)	1682 (±213)	2382 (±68)	1813 (±283)
ə,œ	465 (±85)	1527 (±141)	2404 (±81)	1591 (±182)

**F1<sub>SPAN</sub>**: 451 (±64)   **F2<sub>SPAN</sub>**: 1461 (±127)   **Area**: 36.76 (±7.01)

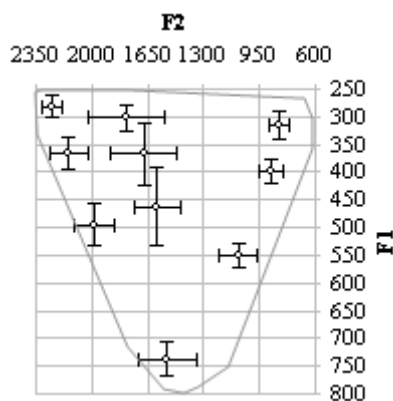


**Languages:** Breton (bre), Chong (cog), Emilian (egl), Frisian (fry), Scottish Gaelic (gla), Hungarian (hun:3), Khmer (khm:2), Dutch (nld:15-18), Wa (prk), Romanian (ron:2), Thai (tha), Wu (wuu:3)

## 7S3a:

IPA	F1	F2	F3	F2'
i	282 (±20)	2247 (±62)	2935 (±65)	2828 (±150)
ɨ	366 (±30)	2142 (±121)	2791 (±103)	2541 (±233)
ɛ	495 (±39)	1985 (±127)	2629 (±80)	2219 (±200)
a	738 (±31)	1529 (±180)	2513 (±35)	1576 (±222)
ʌ,ɔ	551 (±23)	1085 (±123)		1085 (±123)
o	397 (±21)	878 (±75)		878 (±75)
u	315 (±25)	823 (±63)		823 (±63)
ɨ,y	301 (±23)	1783 (±243)	2384 (±42)	1950 (±329)
ɨ,ɨ	367 (±55)	1674 (±205)	2388 (±36)	1794 (±282)
ə,œ	463 (±71)	1592 (±145)	2423 (±42)	1675 (±196)

**F1<sub>SPAN</sub>**: 456 (±49)   **F2<sub>SPAN</sub>**: 1432 (±111)   **Area**: 36.54 (±8.15)

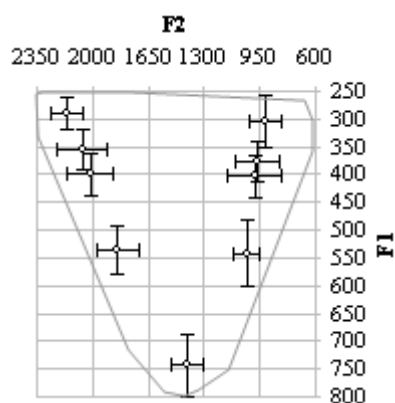


**Languages:** Danish (dan), French (fra:1-3), Megleno-Romanian (ruq), Wu (wuu:4), Paici (pri)

## 9S0:

IPA	F1	F2	F3	F2'
i	288 (±29)	2160 (±104)	2866 (±86)	2652 (±210)
ɨ	355 (±37)	2066 (±155)	2753 (±118)	2426 (±288)
e	400 (±38)	2014 (±148)	2691 (±95)	2306 (±243)
ɛ	536 (±43)	1842 (±134)	2553 (±62)	2002 (±193)
a	743 (±57)	1409 (±100)	2493 (±25)	1431 (±115)
ɔ	542 (±60)	1030 (±82)		1030 (±82)
ɔ	403 (±39)	982 (±171)		982 (±171)
u	376 (±36)	966 (±134)		966 (±134)
u	304 (±46)	915 (±106)		915 (±106)

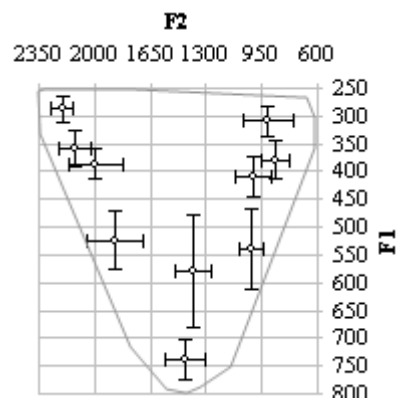
**F1<sub>SPAN</sub>**: 459 (±92)   **F2<sub>SPAN</sub>**: 1313 (±195)   **Area**: 33.95 (±12.55)



**Languages:** Akan (aka), Foodo (fod), Konni (kma), Baale (koe), Dholuo (luo), Maa (mas), Mangbetu (mdj), Majang (mpe:1), Nawuri (naw), Sotho (sot), Twi (twi), Yoruba (yor:4-5)

**9S1:**

IPA	F1	F2	F3	F2'
i	288 (±23)	2204 (±66)	2896 (±61)	2732 (±142)
ɪ, e	359 (±33)	2122 (±99)	2781 (±80)	2508 (±182)
e, ɪ	386 (±26)	1995 (±168)	2689 (±103)	2284 (±275)
ɛ	524 (±53)	1872 (±182)	2575 (±88)	2051 (±266)
a	738 (±36)	1430 (±122)	2509 (±17)	1457 (±135)
ɔ	540 (±73)	1013 (±74)		1013 (±74)
ɒ, ɔ	409 (±37)	1000 (±115)		1000 (±115)
u, ɔ	379 (±35)	865 (±83)		865 (±83)
ʊ	309 (±28)	909 (±153)		909 (±153)
ɜ	580 (±102)	1385 (±115)	2461 (±51)	1408 (±136)



**F1<sub>SPAN</sub>**: 452 (±59) **F2<sub>SPAN</sub>**: 1386 (±122) **Area**: 33.90 (±8.30)

**Languages:** Degema (deg), English (eng:32-33), Ikposo (kpo), Lango (laj), Mayogo (mdm), Majang (mpe:2), Kinande (nmb), Lubwisi (tlj),

**Structures occurring in four languages in the survey:**

**3S2:**

IPA	F1	F2	F3	F2'
ɨ	308	2313	2969	2934
ɘ	725	1310	2514	1320
ɚ	366	731		731
y	299	1799	2357	1970
ɚ, œ	460	1532	2429	1595

**Languages:** Mandarin (cmn), English (eng:1-8), Ao (njo), Dutch (nld:3-5)

**6R1:**

IPA	F1	F2	F3	F2'
ɨ	318	2219	2889	2737
ɛ̃	489	1921	2596	2125
ã	682	1470	2479	1504
ʌ, ɔ̃	579	1163		1163
õ	454	910		910
ũ	354	894		894
ə	413	1471	2371	1526

**Languages:** Catalan (cat:4), Korean (kor:4), Ayutla Mixe (mxp), Ticuna (tea)

**6R2a:**

IPA	F1	F2	F3	F2'
i	287	2213	2914	2782
e	420	2080	2749	2452
a	746	1573	2517	1624
ɒ	610	1068		1068
õ	490	975		975
u	310	817		817
ɨ, ʏ	313	1616	2338	1723
ɚ, œ	447	1492	2396	1547

**Languages:** Estonian (ekk:6), Fe'fe' (fmp), Khmer (khm:1), Mono (mnh)

**6L3b:**

IPA	F1	F2	F3	F2'
ɨ	324	2271	2923	2828
ɛ̃	445	2045	2685	2334
æ̃	590	1742	2544	1874
ã	693	1273		1273
ɔ̃	478	849		849
ɚ	358	806		806
y	332	1979	2449	2212
œ	515	1479	2444	1531
ə	456	1406	2373	1438

**Languages:** Afrikaans (afr:2), Chuvash (chv), Estonian (ekk:4-5), Voru (vro:1)

**6R3:**

IPA	F1	F2	F3	F2'
ɨ	305	2226	2911	2785
ɛ̃	453	2019	2662	2283
ɘ	717	1516	2505	1558
ɔ̃, ɔ̃	660	1118	2439	1124
ɔ̃	456	906		906
ɚ	333	825		825
y	307	1984	2431	2214
ø	432	1570	2383	1646
ɚ, ɚ	403	1449	2351	1492

**Languages:** Estonian (ekk:7-12), Norwegian (nor), Toda (tex), Wu (wuu:2)