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## Diphthongs in Urdu Language and Analysis of their Acoustic Properties

**Abstract:** In addition to the vowels and consonants, the Urdu language has also got some diphthongs. This paper demonstrates a survey to identify the Urdu diphthongs and an analysis of their acoustic properties. The variation in acoustics properties of diphthongs across and within various speakers (both males and females) is discussed.

**Keywords:** Onglide, Offglide, Rising Diphthongs, Falling Diphthongs, Template, Formants, Coarticulation, Stress.

### 1. INTRODUCTION

A diphthong is a combination of two vowels. Diphthongs are basically vowels but they possess quality of two vowels i.e. they present the sound of two vowels. In a diphthong, the articulatory mechanism moves continuously from an initial vowel position to a final vowel position. In simple vowels, or monophthongs, the tongue body has a relatively stable position throughout. But there are other vowels where the tongue body does not stay in one place, even in the most abstract diagrams with artificial slices. Thus, diphthongs are complex vowels that are characterized by movement.

The acoustic pattern of diphthongs changes gradually due to change in vocal tract configuration of the vowels forming the diphthongs.

Diphthongs often do not begin and end with any of the sounds that occur in simple vowels but start from more or less the low central vowel position midway between any two vowels.

### 2. LITERATURE REVIEW

The first part of a diphthong is usually more prominent than the last part and such diphthongs are called Falling Diphthongs. In fact, the last part is often so brief and transitory that it is difficult to determine its exact quality. In diphthongs where the last part is longer than the first part are called Rising Diphthongs. [Ladefoged]

Diphthongs and glides are associated with gradually changing formant structure. The acoustic theory developed earlier for vowels applies in general form to any given configuration in the dynamic complex. For instance, the diphthong /ai/ involves a series of vocal tract configurations running from the onglide [a] to the offglide [i]. [Kent]

Articulatory movement, particularly of the tongue, occupies a substantial portion of a diphthong, which can be defined in terms of two vocalic targets that determine the range and direction of the glide between them. Traditionally the diphthongs produced with a tongue movement from a

mid or low to a high position are known as closing diphthongs while those produced from a peripheral to a central position are known as centering diphthongs. [Clark]

Urdu has 7 long vowels, 3 short vowels and 6 nasalized long vowels. Phonemically there are no diphthongs in Urdu ([Bokhari] [Alam]) as are found in English and other such languages but ε and ɔ, vowels can be converted into diphthongs in certain intonation of certain Indian languages. The reason for absence of diphthongs in Urdu maybe that while speaking Urdu, we tend to break the clusters present in words. For instance in “waqt” that means ‘time’ in Urdu we tend to say ‘vəkət’ instead of ‘vəkt’ so in such languages diphthongs are less likely to exist. But there are chances of exploitation of diphthongs in Urdu.

A diphthong must exist in a single template. The templates of Urdu language do not support two vowels coming together as indicated by following templates:

- (V) e.g. /a:/, /o:/, /e:/ etc.
- (VC) e.g. /əb/, /un/, /ɪs/, /us/ etc.
- (CV) e.g. /ka/, /ki/, /dʒa/, /la:/ etc.
- (CVC) e.g. /dʒa:n/, /kʰel/, /ka:m/ etc.
- (VCC) e.g. /əsl/, /əbd/, /ɪfk/, /dʰərm/ etc.
- (CVCC) e.g. /dost/, /mulk/, /vəkt/, /goʃt/ etc.

(C is for Consonants and V for Vowels).

CVC has central importance in Urdu templates. [Alam]

In order to produce diphthongs in Urdu timing slots are deleted. For instance “dʒaʔo” has the following vowel and consonant segments CV.CC. The deletion rule results in the deletion of the consonant “ʔ” and the resulting phonetic transcription is “dʒaʔo”. It has a pattern CV.V. As a syllable cannot begin with a vowel therefore the vowel “o”, combines with the preceding syllable to form the pattern CVV. Heavy syllables are not allowed in Urdu therefore a timing slot is deleted.

### 3. METHODOLOGY

#### 3.1 Procedure

A list of 24 Urdu words consisting of various diphthongs according to our perception was selected. Equal number of words that were without diphthongs were added to the list and the resulting list was randomized so that the recognition of one diphthong is not affected by the preceding and the following diphthong. The final list was then circulated among 30 subjects who were trained to identify the syllables in a word. To investigate the diphthong pattern we used Urdu speakers with a Punjabi

background. The speakers were familiar with both Urdu and Punjabi but their native language was Urdu. They were then asked to identify the number of syllables in each word of the list.

After the selection of diphthongs an acoustic analysis was conducted to identify the variation in the behavior of diphthongs in the following categories:

- Variation across male and female speakers
- Variation within a speaker

In order to achieve the goal, 6 subjects were selected among which three were males and the rest were females. It was kept in mind that the subjects were of different ages and heights as the length of vocal tract varies with height and fundamental frequency varies with gender. Each speaker was given 17 flash cards. Each flash card contained a diphthong in a carrier sentence. The reason for recording diphthongs in a carrier sentence is that the context remains same and we get a stressed diphthong. Speakers were asked to record each sentence three times.

A diphthong being a combination of two vowels has three critical points where their formants present some meaningful information. These critical points are:

- *Onglide* of a diphthong which represents only the first vowel of the diphthong
- *Transition* phase in which a shift from first vowel to the second one occurs.
- *Offglide* of a diphthong which represents the last vowel in the diphthong.

### 3.2 Data Recording and Analysis

Recording of the diphthongs was done on PRAAT 4.1 a speech processing tool designed for windows users. The recorded wave file was used for acoustic analysis in PRAAT 4.1. The equipment consisted of two high quality speakers with 8 ohm impedance, a Teac integrated stereo amplifier and a high fidelity microphone.

From the recorded data the diphthongs were extracted and the acoustic pattern was analyzed at the above mentioned three critical points. At these points values of F1, F2, and F3 were noted.

## 4. RESULTS

The results were collected in the following table along with different diphthongs in Urdu language, as identified by us.

Table 1: Result of Survey of 30 Native Urdu Speakers

Sr. #	Diphthong	Occurrence	Result
1	ɪa	Kɪa	Considered
2	aũ	k <sup>h</sup> aũ	Considered
3	oi	roi	Considered
4	ae	ae	Considered
5	oĩ	roĩ	Considered
6	uɑ̃	kuɑ̃	Not considered
7	əi	Kəi	Considered
8	iõ	rotiõ	Not considered

9	aē	Dʒaē	Considered
10	ia	kia	Not considered
11	oə	moətbər	Not considered
12	əa	Gəa	Considered
13	iũ	kiũ	Considered
14	ai	ai	Considered
15	ao	Dʒao	Considered
16	iã	miɑ̃	Not considered
17	oe	roe	Considered
18	əĩ	Gəĩ	Considered
19	æe	Gæe	Considered
20	ua	hua	Considered
21	ue	hue	Considered
22	ɔə	mɔətər	Not considered
23	ui	hui	Considered
24	ɪe	Lɪe	Not considered
25	ɪē	Prē	Not considered

As a result of this analysis the words containing only one syllable were selected as diphthongs. The strategy for the selection was that if a word was considered as diphthong by more than 15 subjects then it was included in the list of actual diphthongs.

Second column in the table shows the possible diphthongs in Urdu. The next column shows the occurrence of the particular diphthong in Urdu words. The remaining two columns indicate the result and vote count respectively. Out of the 17 identified, 4 are nasalized.

## 5. DISCUSSION

The diphthongs that have been discussed in our paper may not be the only diphthongs present in Urdu. Identification of a diphthong varies with the subject's perception. We have considered the combination of two vowels in a word as a diphthong if more than 15 native speakers accepted. There were cases in which 12, 13 or 14 subjects voted for a particular diphthong, but we rejected such close options as we had settled a limit. Diphthongs present in the words like "rotiõ", "miɑ̃" and "kia" were considered by a lot of subjects but since they were below the settled limit so they were not included in the final list. Figures 1-4 show the diphthong pattern of Urdu as observed from the analyzed data. The graphs were plotted using the average values from the analyzed data given in Appendix A.

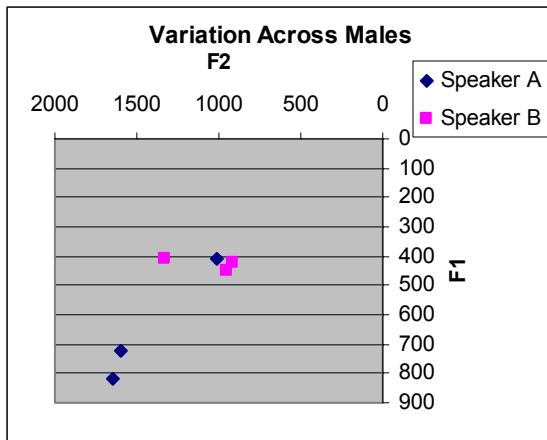


Figure 1

Figure 1 shows the representation of the diphthong in “d3ao”, that is a verb in Urdu and it means “to go”. It is represented using the F1-F2 trajectories. This graph shows the variation in this diphthong between two male speakers of different height and age. Analysis of the graph shows that in speaker A’s data there is a falling diphthong whereas in speaker B’s data it is a rising diphthong. It has also been observed for speaker A that the second vowel “o” in the diphthong is stressed and its formants are very close to the formant values of the original cardinal vowel “o”. It is similar for speaker B because in his data the first vowel “a” is stressed and its formants are very close to the formant values of the original cardinal vowel “a”. The pitch of a speaker’s voice varies with the physiological imposed limits of pitch range which derives from his/her own personal laryngeal anatomy. Pitch pattern for speaker A is rising and for speaker B it is falling.

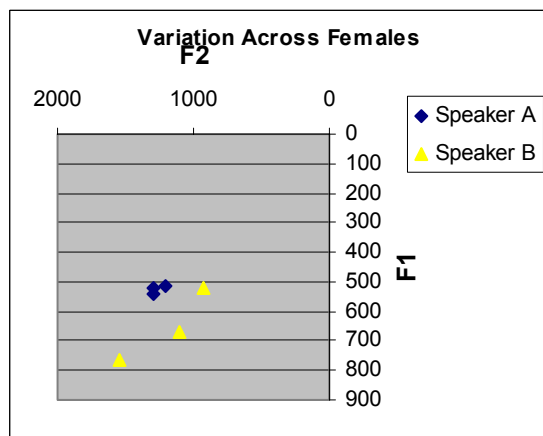


Figure 2

Figure 2 shows the variation of same diphthong in “d3ao” between two females. In speaker A’s data there is little stress that corresponds to less coarticulation. For speaker B there is more coarticulation as the data shows more stress. Duration is also greater for speaker B. Speaker A’s diphthong is a rising whereas speaker B’s diphthong is a falling diphthong. The pitch pattern for Speaker A is falling and that for Speaker B is rising.

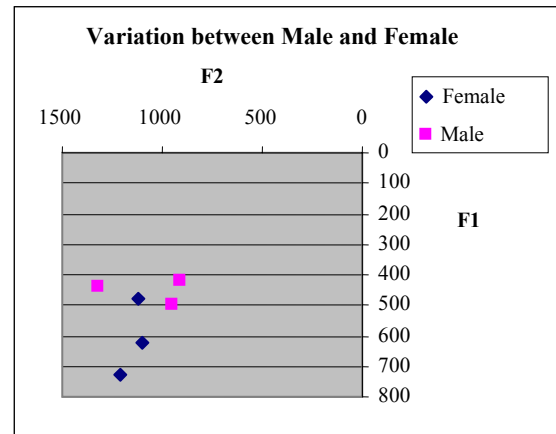


Figure 3

In figure 3 there was a great deal of variation between male and female speakers. There was a significant difference in F0 of male and female speaker as their vocal tract configuration differs.

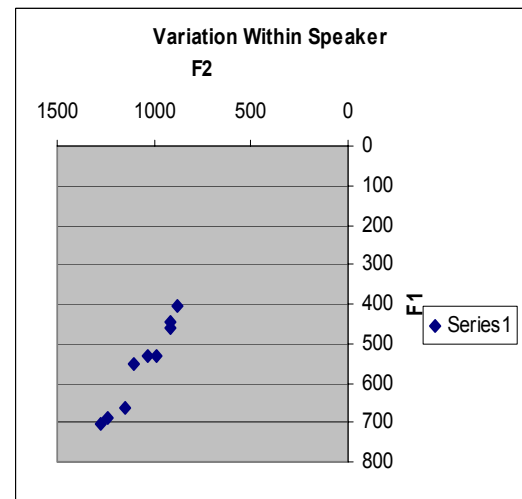


Figure 3

Closer look to the data shown in Figure 4 indicates that not necessarily all the three formants gain identical transition rates for a particular diphthong. Data collected for the three occurrences of the diphthong in word “d3ao” for the same speaker gave an almost identical average value for F1 for all the occurrences but at the same time there was great variation in F2 for the same diphthong.

Table 2: Averages of F0 of Speakers

Sr. no	Diphthong	F0
1	ai	219.72
2	ae	226.73
3	ao	218.67
4	lũ	246.15
5	ra	223.77
6	aũ	221.08
7	oi	215.46
8	oe	211.15
9	oĩ	217.83

10	əi	217.82
11	aē	216.30
12	ea	205.17
13	əĩ	225.03
14	ua	211.01
15	ui	218.74
16	ue	204.50
17	æe	204.44

### 5.1 Fundamental Frequency Variation

It was observed that the fundamental frequency is less for diphthongs starting with open vowels and more for the ones starting with lesser open vowels. It follows the same trend throughout the sample. It is highest for diphthongs starting with “i” and lowest for the ones starting with “u”.

### 5.2 Diphthongs in Cardinal Vowels Quadrilateral

The position of the diphthongs in the cardinal vowel quadrilateral was expected to be between the two cardinal vowels whose combination is the corresponding diphthong. But the situation is practically not like that.

One of the example is of diphthong “ai”, that means ‘to come’ in Urdu. It is expected that onglide of the diphthong should be closer to “a” and the offglide should be closer to “i”. But according to Figure 5 onglides of all the diphthongs that start with “ə” and “a” map on to the vowel “œ”. This is proved by the formant values given in the appendix A. If we consider the diphthong “ao” then it is observed that it is closer to “ɔ” in the cardinal vowel quadrilateral that is between the vowels “a” and “o”. As we

know that the formant values of F1 and F2 in the vowel “a” are 700 Hz and 1100Hz respectively and that of “o” are 400Hz and 900Hz respectively. F1 and F2 of “ao” are 552Hz and 1104Hz.

### 6. CONCLUSION

According to our observations the acoustics of diphthongs are dependent to a great extent on speed of utterance, intonation, tone and rhythm. In English the syllabic stress is of great importance in the utterance of diphthongs but according to our experimentations and observations it does not play much role in the phonemics of Urdu diphthongs.

### 7. SUMMARY

The selection of diphthongs as discussed in the paper depends upon the perception of subjects, which may vary if same survey is conducted for different subjects. So the number of identified diphthongs is not fixed. The acoustic patterns as observed show that a diphthong has three critical points namely onglide, offglide and transition. At transition point a shift between two vowels was observed.

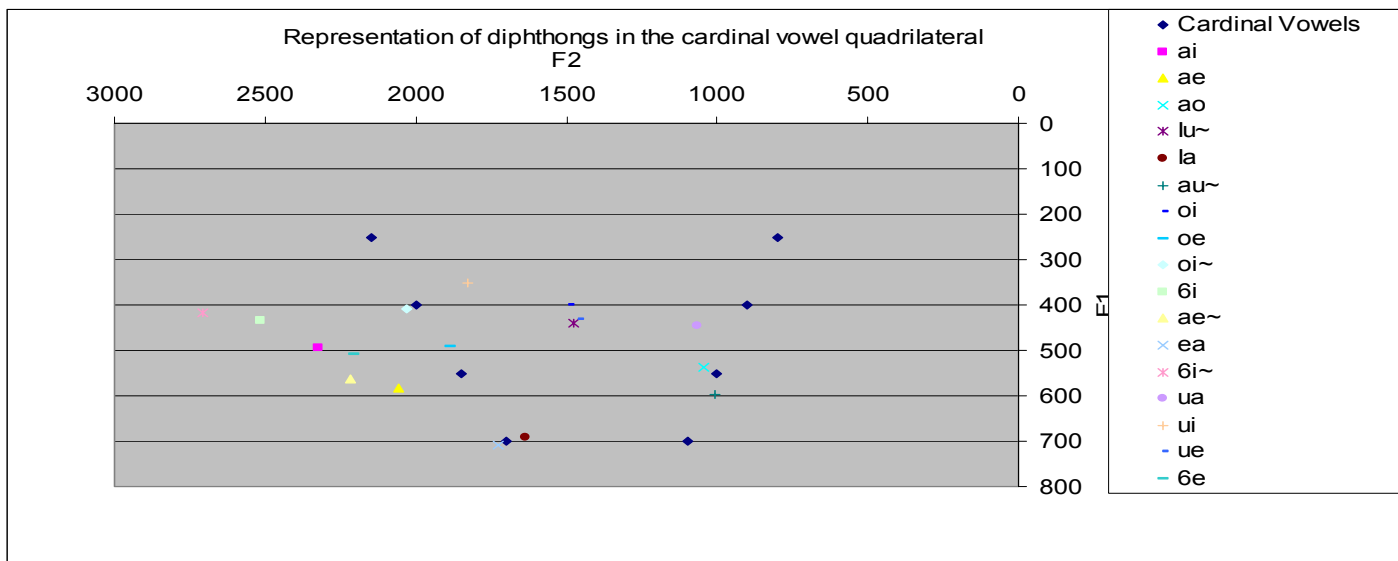


Figure 5

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## APPENDIX A

Speaker	diphthong	F1	F2	F3	F1	F2	F3	F1	F2	F3
1	ai	874.715619 821.046507 851.236057	1483.058812 1530.217905 1606.798322	3215.581387 3106.674304 3172.936585	416.228293 530.422962 533.346767	2625.254397 2184.298872 2153.227948	3206.804183 2993.489952 3106.679623	326.384134 360.856802 363.899682	2921.968632 2847.701922 2838.081255	3399.947853 3305.701938 3291.046491
	ae	852.560240 876.849194 871.426372	1437.504192 1577.632355 1674.196793	3016.550361 3236.538929 3078.575832	639.636913 448.275574 664.816803	1771.741907 2398.385254 1996.492757	3285.582757 3077.243408 2958.524733	424.552561 426.088026 401.270652	2565.729303 2626.176521 2577.518650	3126.975022 3101.596398 2977.445518
	ao	703.313106 690.773557 663.502423	1278.821465 1235.386136 1149.754899	2986.214386 2808.771336 2471.837519	552.248417 529.172584 529.657057	1104.991982 1034.901182 986.674492	2968.863748 2940.018320 2751.953998	444.270311 460.274822 405.720517	911.780209 912.023009 880.363518	2966.195095 2971.693542 2793.195312
	iu~	438.205741 414.967593 384.464597	1861.888938 1938.019496 2134.848287	2836.418461 2667.431968 2678.778723	452.726309 435.183717 431.418539	1257.299091 1385.225496 1782.780643	2857.577813 2831.290970 2766.021314	295.032732 385.745477 433.888443	723.069222 874.162494 1080.711054	2695.221562 2659.227132 2609.973346
	□a	658.133595 571.195347 622.179989	1922.794051 1855.751954 1813.559600	2789.960459 2840.333767 2734.763241	746.347245 664.090725 660.582558	1599.561366 1653.868004 1649.460614	2866.186005 2807.087153 2741.436691	779.020939 806.761571 745.740565	1359.046297 1313.337128 1298.052210	2977.428727 2874.869827 2969.704726
	au~	793.766792 712.287150 794.932908	1279.325658 1267.999838 1258.168863	3274.147994 2976.007816 2842.164305	635.105373 635.812484 519.001595	1044.542738 1125.188259 853.614248	2983.465503 2602.873883 2563.588000	557.947402 491.913254 405.979873	2931.920580 864.268780 1050.966518	3784.662900 2664.093551 2664.069879
	oi	409.525161 413.110043 419.921938	1343.677988 1106.270561 1165.905039	2747.453195 2831.127099 2800.967837	394.590732 409.035667 396.184642	1757.642874 1164.003822 1561.555971	2683.167292 2749.334181 2668.961736	328.334800 387.257540 368.361467	2853.061755 2556.140617 2689.575227	3106.814043 2841.141791 2971.308262
	oe	507.787902 497.205581 519.313342	1400.802142 1514.285558 1425.048334	2714.674521 2660.726566 2641.185598	502.291734 485.244795 485.124419	1892.371803 1892.095496 1867.028521	2682.634430 2637.372673 2547.165979	416.764883 395.428037 393.132936	2442.786391 2469.314152 2378.205565	2720.283057 2667.264297 2843.815213
	oi~	440.785231 455.827009 436.877673	1578.747945 1555.831076 1387.398953	2673.665122 2750.987812 2517.803745	397.203278 414.270661 411.324126	2134.814022 2046.438485 1908.058461	2719.178622 2759.786558 2557.521177	396.736710 373.428286 389.946769	2963.233834 530.926548 3038.012541	3411.069468 3149.630316 3542.072985

	ai	504.761179 521.816407 440.107516	2159.926112 1970.178793 2315.454852	2829.554957 2730.449008 2895.093978	451.937809 436.290510 414.094705	2472.667815 2506.224254 2574.001807	2968.575178 2984.550810 3091.765446	306.130600 355.040337 341.336463	2835.757008 2756.523966 2776.818824	3022.466414 3202.859729 3228.776473
	aē	587.320526 674.247477 600.350080	2134.517988 1773.387370 1802.275349	3065.397384 3053.402570 2958.205851	516.038550 611.605118 556.894512	2340.996046 2100.129094 2203.924231	3096.858252 3049.149393 3031.510612	427.224652 469.129741 500.443772	2623.703236 2464.570688 2475.557477	3282.852322 3126.572766 3099.618623
	əa	556.458713 529.731760 571.583352	2080.505821 2191.644946 2046.280979	2815.070332 2831.797352 2776.734241	669.464371 707.770511 752.724008	1717.862271 1781.777489 1683.031769	2880.181246 2850.556122 2828.474723	765.289638 808.611461 735.692352	1388.970740 1404.309886 1308.266450	2855.062292 2948.753902 2752.116597
	aĩ	478.031987 454.995415 451.862184	2050.135074 2405.575139 2324.919164	2996.288800 3048.136621 2998.652642	420.791812 413.434659 415.017941	2550.135671 2851.685945 2723.410557	3054.469722 3391.815868 3192.959278	400.751352 411.524217 387.274214	3044.565931 3051.059604 2349.679483	3528.496807 3545.656365 3183.367006
	ua	386.717446 428.535346 325.898317	838.882314 988.468483 758.487539	2936.727224 2969.248194 2676.991162	467.580556 519.008088 351.519847	1121.084887 1195.389173 887.988209	2909.655850 2790.414614 3061.774582	706.089718 736.391837 633.790456	1318.848151 1257.754712 1209.426814	3026.630478 2922.102591 2854.758248
	ui	293.418889 382.991750 385.745162	1311.831247 1078.450522 1078.101824	2694.513499 2707.230399 2686.806427	277.609704 393.463630 383.164003	2173.379650 1498.644700 1807.890319	2717.551835 2626.781657 2589.944253	292.833157 333.145690 333.175891	2612.043993 2632.246013 2660.453160	2955.746572 2718.506965 2632.646112
	ue	337.379913 332.134702 299.999908	866.866000 969.979578 917.035736	2733.534165 2706.284736 2452.610478	418.668745 435.485924 442.632926	1380.619888 1589.970994 1410.021913	2743.492781 2716.636394 2681.626441	437.732730 442.398058 411.371732	2117.203302 2089.990010 2080.640491	2741.728843 2686.460880 2672.713330
	əe	542.681113 535.417692 488.410433	2007.859503 2020.940274 2021.310018	2813.135196 2846.871141 2835.198684	527.894597 532.981245 466.744946	2214.289530 2189.782580 2213.315129	2893.110112 2879.623329 2894.858969	430.544832 453.077628 433.158451	2403.823821 2446.834067 2346.107229	2882.999063 3108.682167 2864.558608
2	ai	877.594710 930.057579 857.509541	1660.312008 1476.527398 1607.829606	2962.498983 3024.672084 2948.152372	633.938713 708.189861 670.711526	2115.668233 1761.016995 1831.931550	2948.602030 2857.121569 2618.839808	393.473637 362.530473 368.203477	1896.355141 2978.891061 2761.746335	3101.385582 3255.000675 3172.727850
	ae	843.854189 845.624814 845.432435	1463.040736 1478.623325 1462.635198	2849.621146 2814.467867 2827.111794	719.068262 666.487467 721.356089	2027.442441 2116.927975 2023.702454	3000.177506 3012.779302 2964.480419	518.970543 495.191083 472.604110	2542.473839 2496.201537 2501.421637	3084.266091 3128.749575 3050.225534
	ao	708.558661 794.926929 676.564395	1222.844595 1262.453804 1147.453798	2780.750318 2789.423260 2951.933644	615.701502 778.962058 464.395645	1061.198981 1297.289728 937.995670	2760.335865 2683.452425 3002.760192	294.336388 490.644489 647.490242	805.056341 930.474690 1630.465592	3019.809906 3179.610917 3065.511464
	iū̃	457.216374 463.152133 441.653899	1844.404294 2263.730257 2516.517483	2731.349477 2737.705741 2763.961138	546.311949 536.198518 425.151495	1914.532029 1174.152745 1515.380323	2711.622542 2647.530208 2812.062477	494.842171 531.368742 577.658744	2402.790808 2184.577835 2287.323489	3035.129325 3078.365209 3249.145804
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	aũ	707.872647 776.203861 765.677003	1163.326464 1158.828328 1103.604570	3499.127164 3081.393324 2849.792026	531.669772 495.329025 476.109407	996.129928 927.629230 1016.178831	2705.529609 2529.296549 2742.638882	486.970730 665.918662 371.424138	2418.749350 1342.140706 779.800022	3067.167465 2856.774650 2733.754425
	oi	468.429973 447.279375 417.473550	1463.844285 1402.199325 1252.258313	2675.582693 2797.240674 2629.586784	460.007036 443.933131 391.318674	2195.516276 2286.236289 2119.930903	2807.849353 2798.128642 2936.712893	310.924444 289.105534 283.592234	2817.455375 2056.715636 1643.624685	2948.092709 3119.234758 3102.781096
	oe	483.016975 474.242289 504.838640	1312.237037 1249.792842 1487.620135	2659.103960 2780.541361 2545.674529	507.097577 500.991390 528.176207	1836.344043 1960.827240 2013.518856	2600.274685 2697.200691 2513.373346	484.944609 474.525319 403.557770	2291.158591 2463.445804 2512.410506	2790.940397 2831.408188 2839.479494
	oĩ	467.553510 444.682763 435.130333	1217.136366 1581.899922 1596.001777	2482.792190 2766.897696 2938.654040	476.692869 435.790243 409.930660	2371.119936 2213.545833 2161.975090	2989.169668 3002.971213 2923.570846	321.503665 431.042907 392.682609	3037.674512 3044.799317 2511.011680	3519.735156 3481.334604 3297.188071
	ai	506.150076 519.906602 573.354190	2197.331480 2234.907700 2144.233702	2851.002521 2863.571240 2850.984388	434.780700 422.550655 400.107396	2614.276012 2551.410821 2601.322380	3032.525496 2915.521756 3041.036753	300.597786 312.712853 347.898906	2926.723287 2816.400964 2739.397222	3459.055912 3193.736867 3320.946421
	aē	747.229223 788.668249	1633.609730 1806.686325	3151.664442 3086.856993	571.533743 690.335933	2201.008458 2141.182905	3214.276839 3103.564563	461.146696 461.089998	2766.893073 2620.119422	3020.695241 2963.664410

		644.706733	1658.397056	2391.299469	499.056064	2537.188197	3340.547235	415.432844	2791.955636	3279.133892
	əa	623.351094 609.761941 526.092202	2239.257627 2162.058864 2458.000245	2950.649275 2795.296774 2905.218797	756.855680 713.020843 641.956913	1898.475419 1877.967630 1974.006776	2855.903946 2874.003483 2835.987032	857.485152 812.088720 786.887316	1480.944499 1606.649461 1490.371769	2935.375923 2990.886694 3154.557948
	əĩ	440.958093 427.882387 417.300191	2684.964996 2786.970093 2514.216648	3146.072523 3135.072538 3031.155308	377.222211 354.000132 402.483559	2759.298022 2552.647842 2865.365926	3161.919739 3222.471338 3189.537418	299.315348 280.578841 384.699930	2454.848510 2245.943068 2795.432615	3264.205830 3161.903493 3387.313980
	ua	425.819503 344.415899 456.075583	1146.312132 1230.361753 1330.239923	2619.536141 2299.310683 2062.741826	581.719305 507.631565 516.766317	1349.994632 1233.800842 1126.689982	2542.446547 2438.935802 2823.876706	730.698672 660.740997 675.539232	1376.142369 1302.633605 1108.440675	2897.258903 2732.724155 2828.341563
	ui	339.042893 338.026749 318.100905	804.007545 870.181429 1710.237329	2751.252101 2843.128947 2698.011071	305.535204 344.768482 271.303649	2139.260541 2079.633508 2622.308933	2723.510982 2726.269075 2866.306135	303.847376 289.522092 249.398040	2758.911031 2796.589947 2797.278233	3215.144375 3279.129636 2858.933524
	ue	583.975338 513.287035 404.923661	1495.050904 1579.308031 1083.306923	2910.032357 2902.671014 2270.809646	512.400988 464.382398 480.502205	1497.109344 1320.639489 2263.470752	2608.402773 2654.925693 3019.310089	482.390418 471.733690 368.805528	2330.305931 2038.052497 2593.596438	2855.607749 2879.294424 3060.828285