

Sound	x_{lar}	A_{lar}	$n_{\text{lar,p}}$	x_{p}	A_{p}	$n_{\text{p,c}}$	x_{c}	A_{c}	n_{c}	x_{a}	A_{a}	$n_{\text{c,a}}$	x_{in}	A_{in}	x_{lip}	A_{lip}
/a:/	1.866	1.153	0.418	2.893	5.755	7.363	8.477	0.951	0.852	14.385	6.655	0.543	17.028	2.706	17.099	2.787
/e:/	0.458	1.474	0.208	3.043	7.055	0.833	12.78	0.478	0.473	17.236	3.199	0.586	17.499	3.859	18.142	2.485
/i:/	1.644	2.046	2.391	5.625	8.834	0.955	13.45	0.275	0.298	17.323	4.055	1.408	17.936	2.929	18.136	3.298
/o:/	1.059	1.983	0.217	2.839	7.53	0.722	11.405	0.421	0.4	17.574	14.351	0.736	20.345	2.087	21.425	0.638
/u:/	1.278	1.904	4.252	6.448	8.881	2.13	14.457	0.782	1.043	18.572	9.436	1.019	20.002	2.288	21.519	0.423
/ɛ:/	2.477	0.772	1.066	2.647	3.614	0.773	12.300	1.316	1.635	15.279	2.632	8.927	16.851	4.133	17.422	4.392
/ø:/	0.895	1.460	0.324	3.122	9.609	0.653	14.390	1.305	0.873	18.767	4.274	1.583	19.101	2.221	20.538	0.62
/y:/	1.510	1.776	3.013	6.103	11.572	0.935	15.014	0.597	0.592	18.637	2.741	0.918	19.313	1.044	20.688	0.342
/a/	2.319	0.685	1.268	3.247	4.311	6.154	9.551	0.776	1.593	15.677	8.536	0.725	18.042	3.637	18.421	3.216
/ɛ/	2.756	0.772	1.276	2.643	3.818	0.275	8.136	1.325	0.508	16.795	3.951	0.594	17.38	3.283	17.474	4.015
/i/	1.606	1.958	3.7	6.628	7.822	2.747	12.842	1.155	1.082	16.456	4.364	0.629	17.894	3.368	18.712	2.681
/ɔ/	0.0	0.817	0.428	2.625	4.504	0.941	10.556	0.506	1.798	17.55	10.108	0.808	19.366	2.08	20.241	1.563
/ʊ/	0.863	1.978	0.515	2.098	8.708	0.792	11.086	0.347	0.925	17.442	12.732	0.852	19.684	1.584	20.848	0.816
/œ/	1.634	1.526	0.791	3.369	7.445	1.928	6.158	2.493	5.605	10.767	5.019	0.225	18.042	2.929	19.012	1.405
/ɣ/	0.594	1.167	0.464	2.773	8.247	0.905	12.8	1.894	0.761	16.428	5.053	0.581	18.201	2.858	19.541	0.816
/ə/	0.0	1.077	0.208	3.074	6.256	0.726	12.783	1.456	2.679	16.725	1.773	0.896	17.407	2.575	18.56	1.405
/f/	0.021	0.753	0.18	1.922	6.776	0.367	11.861	1.804	1.319	16.584	3.22	0.743	17.894	0.548	18.302	1.622
/l/	1.013	1.726	0.618	3.139	10.243	0.817	13.349	1.085	0.703	15.843	1.807	1.388	16.374	1.201	18.767	1.796
/s/	0.968	0.855	0.301	2.554	9.109	1.525	14.274	2.416	1.222	16.495	0.092	0.586	17.407	1.301	17.892	1.561
/ʃ/	2.35	1.079	5.222	5.154	9.078	1.301	16.442	0.127	0.438	17.329	6.732	1.77	18.519	1.867	19.765	3.172
/ç/	2.545	0.875	9.361	6.716	6.61	1.002	14.464	0.311	1.5	16.9	0.16	0.57	17.982	2.877	18.812	2.681
/x/	2.406	0.718	0.074	2.406	1.822	0.806	9.412	0.2	0.741	14.815	8.271	1.392	16.93	6.115	17.745	3.708

TABLE I
PARAMETER VALUES FOR THE GEOMETRICALLY FITTED FULL CONFIGURATION OF THE SIX POINT MODEL. ALL POSITIONS x_i , $i \in \{\text{LAR, P, C, A, IN, LIP}\}$, ARE IN cm, ALL AREAS A_i IN cm^2 AND ALL WARPING EXPONENTS n_i ARE DIMENSIONLESS.

Sound	A_{p}	$n_{\text{p,c}}$	x_{c}	A_{c}	n_{c}	A_{a}	$n_{\text{c,a}}$	x_{in}	A_{in}	x_{lip}	A_{lip}
/a:/	5.755	7.363	8.477	0.951	0.852	6.655	0.543	17.028	2.706	17.099	2.787
/e:/	7.055	0.833	12.78	0.478	0.473	3.199	0.586	17.499	3.859	18.142	2.485
/i:/	8.834	0.955	13.45	0.275	0.298	4.055	1.408	17.936	2.929	18.136	3.298
/o:/	7.53	0.722	11.405	0.421	0.4	14.35	0.736	20.345	2.087	21.425	0.638
/u:/	8.881	2.13	14.457	0.782	1.043	9.436	1.019	20.002	2.288	21.519	0.423
/ɛ:/	3.614	0.773	12.3	1.316	1.636	2.632	8.927	16.851	4.133	17.422	4.392
/ø:/	9.609	0.653	14.39	1.305	0.873	4.274	1.583	19.101	2.221	20.538	0.62
/y:/	11.572	0.935	15.014	0.597	0.592	2.741	0.918	19.312	1.044	20.688	0.342
/a/	4.311	6.154	9.551	0.776	1.593	8.537	0.725	18.042	3.637	18.421	3.216
/ɛ/	3.818	0.275	8.136	1.325	0.508	3.951	0.594	17.38	3.283	17.474	4.015
/i/	7.822	2.747	12.842	1.155	1.082	4.364	0.629	17.894	3.368	18.712	2.68
/ɔ/	4.504	0.941	10.556	0.506	1.798	10.108	0.808	19.366	2.08	20.241	1.563
/ʊ/	8.708	0.792	11.086	0.347	0.925	12.732	0.852	19.684	1.584	20.848	0.816
/œ/	7.445	1.928	6.158	2.493	5.605	5.019	0.225	18.042	2.929	19.012	1.405
/ɣ/	8.247	0.905	12.8	1.894	0.761	5.053	0.581	18.201	2.858	19.541	0.816
/ə/	6.256	0.726	12.783	1.456	2.679	1.773	0.896	17.407	2.575	18.56	1.405
/f/	6.776	0.367	11.861	1.804	1.319	3.22	0.743	17.894	0.548	18.302	1.622
/l/	10.243	0.817	13.349	1.085	0.703	1.807	1.388	16.374	1.201	18.767	1.797
/s/	9.109	1.525	14.274	2.416	1.222	0.092	0.586	17.407	1.301	17.892	1.561
/ʃ/	9.078	1.301	16.442	0.127	0.438	6.732	1.77	18.519	1.867	19.765	3.172
/ç/	6.61	1.002	14.464	0.311	1.5	0.16	0.57	17.982	2.877	18.812	2.681
/x/	1.822	0.806	9.412	0.2	0.741	8.271	1.392	16.930	6.115	17.745	3.708

TABLE II
PARAMETER VALUES FOR THE GEOMETRICALLY FITTED REDUCED CONFIGURATION OF THE SIX POINT MODEL. ALL POSITIONS x_i , $i \in \{\text{LAR, P, C, A, IN, LIP}\}$, ARE IN cm, ALL AREAS A_i IN cm^2 AND ALL WARPING EXPONENTS n_i ARE DIMENSIONLESS.

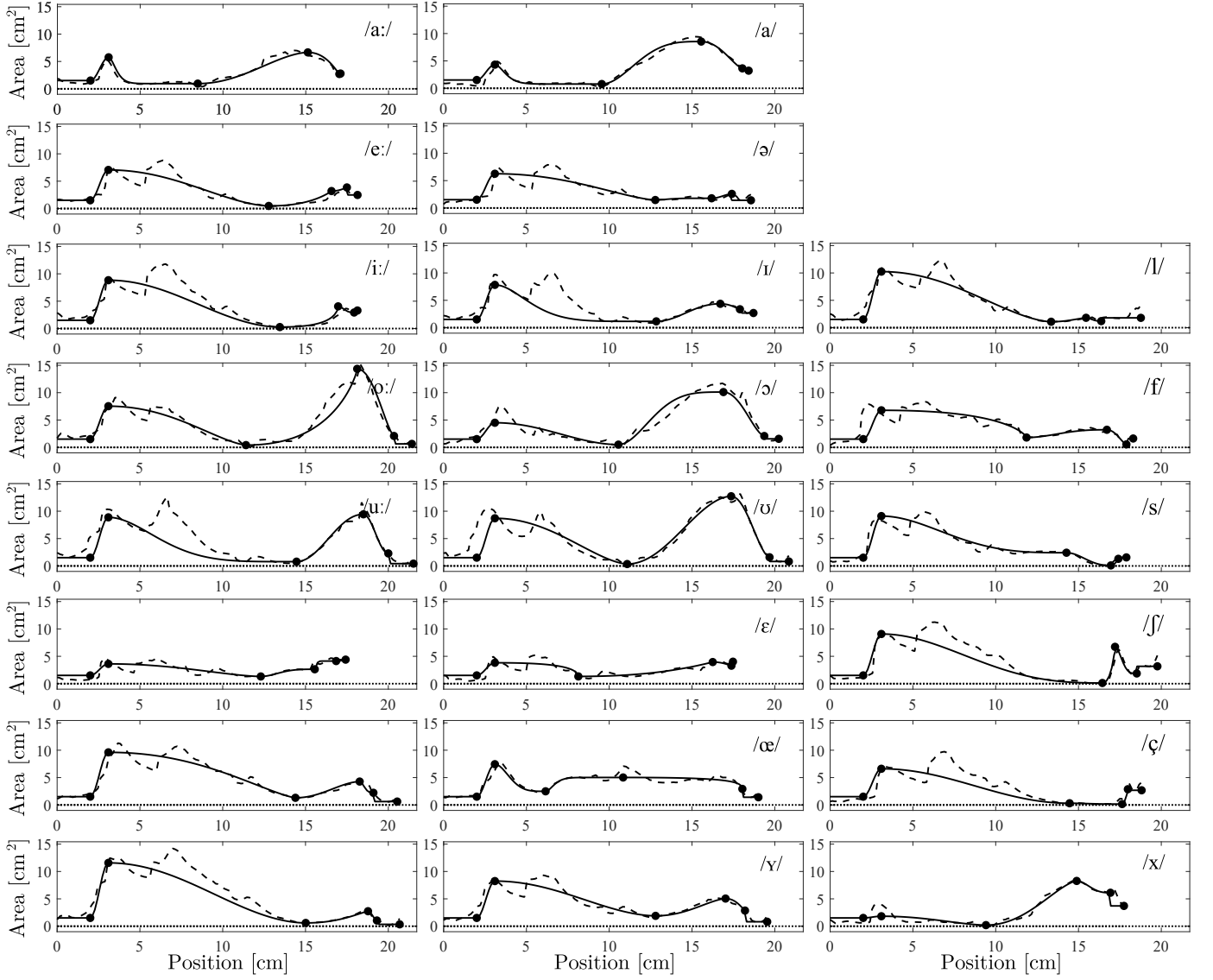


Fig. 1. Area functions of tense vowels (left column), lax and neutral vowels (center column), and consonants (right column). Dashed lines mark the references and solid lines the geometrically fitted reduced configuration of the six point model. The black dots mark the six control points.

Sound	x_{lar}	A_{lar}	$n_{lar,p}$	x_p	A_p	$n_{p,c}$	x_c	A_c	n_c	x_a	A_a	$n_{c,a}$	x_{in}	A_{in}	x_{lip}	A_{lip}
/a:/	2.066	1.143	0.118	2.693	5.745	6.963	8.277	0.941	1.252	14.19	6.665	0.243	16.52	2.83	16.53	2.969
/e:/	0.658	1.464	0.208	2.943	7.045	1.233	12.98	0.488	0.473	17.14	3.189	0.586	17.5	3.859	17.94	2.495
/i:/	2.044	2.026	0.891	3.352	8.991	0.8	13.39	0.216	2.413	16.06	0.714	0.814	17.32	3.421	17.63	2.925
/o:/	1.359	1.963	0.217	2.789	7.51	1.522	11.01	0.441	0.6	17.17	14.33	1.536	20.45	2.107	21.02	0.658
/u:/	1.477	1.894	3.852	6.138	9.035	1.33	14.31	0.628	0.843	18.26	11.42	0.919	20.2	2.545	21.52	0.762
/ɛ:/	2.627	0.762	0.666	2.847	3.624	0.673	12.4	1.306	1.235	15.38	2.622	9.327	16.65	4.143	17.27	4.402
/ø:/	1.295	1.463	0.024	3.122	9.589	0.753	14.74	1.325	1.273	18.82	4.284	1.583	19.1	2.221	20.19	0.64
/y:/	1.91	1.756	2.213	6.103	11.55	0.935	15.41	0.617	0.392	18.69	2.761	0.618	19.46	1.054	20.29	0.362
/a/	2.519	0.675	0.868	3.047	4.301	6.554	9.751	0.786	1.193	15.88	8.527	0.325	18.17	3.647	18.22	3.226
/ɛ/	2.556	0.762	0.876	3.987	3.808	0.375	8.336	1.335	0.308	16.59	3.961	0.194	17.38	3.293	17.4	4.015
/i/	1.806	1.948	3.3	6.428	7.812	2.347	13.04	1.165	0.682	16.66	4.354	0.229	18.09	3.378	18.51	2.691
/ɔ/	0.4	0.797	0.028	2.525	4.484	0.641	10.51	0.526	1.398	17.95	10.09	0.008	19.37	2.06	19.84	1.583
/ʊ/	1.663	1.938	0.015	2.048	8.668	1.992	10.54	0.387	0.325	17.74	12.73	1.052	20.14	1.308	20.14	1.291
/œ/	1.834	1.517	0.391	3.569	7.435	2.328	6.358	2.503	5.205	10.97	5.009	0.625	17.89	2.919	18.81	1.415
/ɤ/	-0.2	1.107	1.508	2.074	6.206	1.926	12.18	1.486	3.879	16.13	1.808	0.496	17.86	1.9	18.76	1.395
/ə/	0.2	1.067	0.108	2.874	6.246	1.126	12.58	1.466	3.079	16.52	1.783	1.296	17.46	2.585	18.36	1.415
/l/	1.017	1.727	0.624	3.149	10.26	0.826	13.4	1.07	0.719	15.67	1.732	1.177	16.33	1.298	18.09	1.721
/f/	0.0	0.75	0.179	1.922	6.799	0.379	11.88	1.878	0.456	14.68	3.321	0.582	17.43	2.504	18.3	0.259
/s/	0.968	0.855	0.301	2.554	9.109	1.525	14.27	2.416	1.222	16.5	0.149	0.586	17.41	1.301	17.89	1.561
/ʃ/	2.35	1.079	5.222	5.154	9.078	1.301	16.44	0.212	0.438	17.33	6.732	1.77	18.52	1.867	19.77	3.172
/ʒ/	1.644	2.046	2.391	5.625	8.834	0.955	14.02	0.202	0.313	15.44	0.569	1.114	17.61	3.255	18.14	3.298
/x/	2.406	0.718	0.074	2.406	1.822	0.806	9.441	0.14	0.741	14.82	8.271	1.392	16.93	6.115	17.75	3.708

TABLE III
PARAMETER VALUES FOR THE PERCEPTUALLY OPTIMIZED FULL CONFIGURATION OF THE SIX POINT MODEL. ALL POSITIONS x_i , $i \in \{\text{LAR}, \text{P}, \text{C}, \text{A}, \text{IN}, \text{LIP}\}$, ARE IN CM, ALL AREAS A_i IN cm^2 AND ALL WARPING EXPONENTS n_i ARE DIMENSIONLESS.

Sound	A_p	$n_{p,c}$	x_c	A_c	n_c	A_a	$n_{c,a}$	x_{in}	A_{in}	x_{lip}	A_{lip}
/a:/	5.735	8.163	8.077	0.971	1.452	6.655	0.543	17.03	2.726	17.05	2.787
/e:/	7.045	1.233	12.58	0.488	0.373	3.189	0.986	17.55	3.869	17.94	2.495
/i:/	8.824	1.055	13.5	0.285	0.198	4.065	1.008	17.74	2.939	17.94	3.298
/o:/	7.52	1.122	11.21	0.431	0.6	14.36	0.736	20.3	2.097	21.23	0.648
/u:/	8.858	1.43	14.41	0.795	0.643	9.421	1.619	19.55	2.273	21.09	0.515
/ɛ:/	3.604	0.873	12.35	1.306	1.435	2.642	9.327	16.65	4.143	17.22	4.402
/ø:/	9.599	0.753	14.59	1.315	1.073	4.264	1.483	19.3	2.211	20.34	0.63
/y:/	11.56	0.935	15.11	0.607	0.192	2.751	0.818	19.16	1.044	20.49	0.352
/a/	4.301	6.554	9.701	0.786	1.193	8.527	0.325	18.17	3.647	18.22	3.226
/ɛ/	3.808	0.375	8.336	1.335	0.408	3.961	0.194	17.38	3.293	17.4	4.015
/i/	7.812	2.347	13.04	1.145	0.682	4.354	0.229	18.09	3.378	18.51	2.691
/ɔ/	4.474	0.641	10.21	0.536	1.698	10.08	0.108	19.69	2.344	19.87	1.622
/ʊ/	8.698	0.592	11.19	0.357	0.525	12.72	1.252	19.88	1.594	20.65	0.826
/œ/	7.425	2.728	6.158	2.513	5.105	4.999	0.925	18.19	2.917	18.61	1.425
/ɤ/	8.217	2.105	12.2	1.924	0.261	5.06	0.981	18.35	2.868	18.94	0.846
/ə/	6.246	1.126	12.58	1.466	3.079	1.783	1.296	17.46	2.585	18.36	1.415
/f/	6.776	0.367	11.86	1.804	1.319	3.22	0.743	17.89	0.272	18.41	0.277
/l/	10.24	0.817	13.35	1.085	0.703	1.807	1.388	16.37	1.201	18.77	1.796
/s/	9.109	1.525	10.71	2.416	1.222	0.134	0.586	17.41	1.301	17.89	1.561
/ʃ/	9.078	1.301	16.11	0.156	0.438	6.622	1.77	18.65	1.895	19.77	3.172
/ʒ/	6.61	1.002	14.52	0.247	1.5	0.192	0.57	17.98	2.877	18.81	2.681
/x/	1.822	0.806	9.412	0.182	0.741	8.271	1.392	16.93	6.115	17.75	3.708

TABLE IV
PARAMETER VALUES FOR THE PERCEPTUALLY OPTIMIZED REDUCED CONFIGURATION OF THE SIX POINT MODEL. ALL POSITIONS x_i ARE IN CM, ALL AREAS A_i IN cm^2 AND ALL WARPING EXPONENTS n_i ARE DIMENSIONLESS.

Sound	F_{116}	F_{111}	F_{216}	F_{211}	F_{316}	F_{311}
/a:/	702	622	1246	1123	2679	2676
/e:/	323	319	2132	2141	2709	2679
/i:/	257	258	2066	2174	3038	3124
/o:/	325	311	601	602	2646	2583
/u:/	265	286	751	848	2122	2161
/ɛ:/	528	504	1905	1832	2591	2550
/ø:/	298	286	1300	1269	2025	2014
/y:/	228	225	1657	1614	2056	2119
/a/	671	569	1130	1106	2487	2432
/ɛ/	523	493	1805	1717	2566	2591
/i/	355	394	1756	1652	2470	2480
/ɔ/	463	453	890	844	2522	2477
/ʊ/	327	287	997	750	2402	2391
/œ/	464	473	1313	1301	2224	2252
/ʏ/	372	380	1366	1290	2380	2316
/ə/	406	390	1626	1607	2520	2477

TABLE V

FORMANT FREQUENCIES IN Hz FOR THE FIRST THREE FORMANTS OF THE VOCAL TRACT TRANSFER FUNCTIONS CALCULATED FROM THE THE PERCEPTUALLY OPTIMIZED FULL CONFIGURATION (SUBSCRIPT 16) AND THE PERCEPTUALLY OPTIMIZED REDUCED CONFIGURATION (SUBSCRIPT 11) OF THE SIX POINT MODEL.