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German fricatives: coda devoicing or positional faithfulness?

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Supplementary materials

Appendix: Statistical comparison between predicted voiceless and voiced fricatives on a speaker-by-speaker basis

Speakers are identified by their number and sex. The number of tokens (*n*) from the predicted voiceless words and the predicted voiced words is listed in column 1. Because speakers differ as to how many tokens are produced with syllabic sonorants (which were excluded), these numbers differ for different speakers. Column 2 shows the phonetic parameters, abbreviated as 'fricdur' for fricative duration, and 'vcdur' for voicing duration (both in ms). Columns 3 and 4 contain the mean values across all the predicted voiceless tokens (abbreviated as 'nv' for non-voiced) and all the predicted voiced tokens (abbreviated 'vd') for each speaker, and columns 5 and 6 contain the corresponding standard deviations.

For some cases, the applicability of t-tests might be challenged in two ways. First, the variances of the two distributions to be compared (vd and nv) were not always the same, as shown by f-tests (see columns 10 and 11). In the cases of $p < 0{\cdot}05$ in column 11, the variances were statistically different. In these cases, a t-test with separate variances was calculated (Welch modification). The values reported in columns 7 to 9 are from a t-test with separate variances if $p \geq 0{\cdot}05$ in column 11, and from a regular t-test if $p < 0{\cdot}05$.

The second problem was that not all data formed a normal distribution. Shapiro-Wilks tests for normal distribution were calculated for predicted voiceless tokens (column 12) and predicted voiced tokens (column 13). Where $p < 0{\cdot}05$ in these columns, the assumption of normal distribution has to be rejected, and hence the applicability of a t-test might be questioned. Applied to the voicing percentage parameter ('vcperc'), the Shapiro-Wilks tests showed that, for almost all speakers, the voiced tokens did not form a normal distribution (probably because the distribution was bimodal – with a second peak around the 100% value). For this reason, the applicability of the t-test for the vcperc parameter was too problematic, and the results for vcperc are not listed here.

The p-values in column 9 indicate whether, for a given speaker, predicted voiced and voiceless fricatives differ in one or more of the two parameters fricdur and vcdur. Since many t-tests were carried out on the same phonetic parameter, the significance levels had to be adjusted. Starting with $p < 0{\cdot}05$, this overall level has to be divided by 31 (speakers), arriving at the new level of $p < 0{\cdot}00161$ for each individual test. All results below this threshold are italicised in column 9. The results show that for 27 out of 31 speakers, at least one of the two phonetic parameters is significantly different in predicted voiced and voiceless fricatives.

[1] In one case (Speaker 18), the Shapiro-Wilks test could not be carried out, because *n* was too small among vd, due to the fact that this speaker produced all but two tokens with a syllabic sonorant.

	1		2	3	4	5	6	7	8	9	10	11	12	13
speaker	*n* nv	vd	para-meter	M nv	M vd	SD nv	SD vd	t-value	df	p	f-ratio variance	p-variance	p-ND nv	p-ND vd
S6 f	12	21	fricdur	105	86	17	10	3·76	31	*0·0006*	2·65	0·055	0·054	0·929
			vcdur	4	9	2	3	−4·03	31	*0·0003*	1·83	0·302	0·013	0·586
S7 m	10	6	fricdur	89	77	17	8	1·55	14	0·1414	4·23	0·126	0·657	0·323
			vcdur	10	77	5	8	−19·19	14	*<0·0001*	2·12	0·307	0·452	0·323
S8 m	12	21	fricdur	87	78	15	6	1·97	13·58	0·0690	4·94	0·001	0·014	0·475
			vcdur	9	32	4	24	−4·29	22·71	*0·0002*	24·85	<0·001	0·988	0·003
S9 f	9	4	fricdur	102	60	10	8	7·18	11	*<0·0001*	1·47	0·821	0·136	0·441
			vcdur	5	37	3	22	−2·83	3·04	0·0644	54·29	<0·001	0·665	0·266
S10 f	10	9	fricdur	96	88	14	13	1·17	17	0·2578	1·17	0·833	0·674	0·469
			vcdur	9	76	5	22	−8·88	8·76	*<0·0001*	18·81	<0·001	0·266	0·706
S11 f	10	20	fricdur	104	84	14	11	3·95	28	*0·0004*	1·75	0·289	0·924	0·397
			vcdur	10	34	5	17	−5·57	25·62	*<0·0001*	9·16	0·001	0·211	0·042
S12 m	11	15	fricdur	103	86	12	15	3·14	24	0·0043	1·43	0·572	0·912	0·580
			vcdur	21	64	11	26	−5·69	19·92	*<0·0001*	5·67	0·008	0·168	0·219
S13 m	12	21	fricdur	114	85	9	12	6·77	31	*<0·0001*	1·59	0·429	0·220	0·647
			vcdur	6	27	5	15	−5·58	26·93	*<0·0001*	8·60	<0·001	0·373	0·054

	1		2	3	4	5	6	7	8	9	10	11	12	13
speaker	*n* nv	*n* vd	para-meter	M nv	M vd	SD nv	SD vd	t-value	df	p	f-ratio variance	p-variance	p-ND nv	p-ND vd
S14 f	12	20	fricdur	87	73	15	9	3·05	30	0·0046	2·65	0·060	0·832	0·247
			vcdur	9	68	7	12	−14·78	30	*<0·0001*	2·94	0·070	0·094	0·779
S15 f	11	19	fricdur	103	85	14	9	4·31	28	*0·0001*	2·51	0·085	0·173	0·098
			vcdur	8	32	5	23	−4·40	20·99	*0·0002*	19·76	<0·001	0·347	0·042
S16 m	9	18	fricdur	93	79	9	14	2·59	25	0·0156	2·36	0·216	0·830	0·189
			vcdur	7	29	3	19	−4·64	19·64	*0·0001*	24·16	<0·001	0·326	0·006
S17 m	11	10	fricdur	85	69	10	13	2·94	19	0·0082	1·92	0·323	0·062	0·397
			vcdur	14	69	5	13	−11·45	11·93	*<0·0001*	5·48	0·013	0·058	0·397
S18 m	11	2	fricdur	88	63	18	24	1·74	11	0·1080	1·64	0·456	0·039	*n too small*
			vcdur	9	63	3	24	−3·13	1·00	0·1949	41·12	<0·001	0·050	
S19 f	11	17	fricdur	89	71	9	8	4·99	26	*<0·0001*	1·46	0·478	0·190	0·599
			vcdur	10	44	4	22	−6·05	18·10	*0·0004*	22·85	<0·001	0·826	0·044
S20 m	10	12	fricdur	85	76	16	4	1·69	10·13	0·1200	13·23	<0·001	0·163	0·829
			vcdur	12	49	3	31	−3·99	11·38	0·0019	68·36	<0·001	0·419	0·003
S21 f	9	12	fricdur	102	71	6	9	8·48	19	*<0·0001*	2·02	0·325	0·022	0·155
			vcdur	7	60	2	17	−10·16	11·54	*<0·0001*	53·78	<0·001	0·612	0·024

	1		2	3	4	5	6	7	8	9	10	11	12	13
speaker	*n* nv	vd	para-meter	M nv	M vd	SD nv	SD vd	t-value	df	p	f-ratio variance	p-variance	p-ND nv	p-ND vd
S22 f	12	21	fricdur	103	101	13	14	0·32	31	0·7446	1·21	0·760	0·938	0·026
			vcdur	10	11	4	5	−0·43	31	0·6669	1·22	0·746	0·199	0·013
S23 m	12	21	fricdur	101	81	19	16	3·19	31	0·0031	1·33	0·552	0·109	0·575
			vcdur	16	59	13	31	−5·45	29·13	*<0·0001*	5·73	0·004	0·003	0·236
S24 f	12	12	fricdur	86	65	13	12	4·05	22	*0·0005*	1·34	0·627	0·339	0·555
			vcdur	11	44	6	23	−4·67	12·51	*0·0004*	14·49	<0·001	0·754	0·031
S25 m	9	20	fricdur	108	81	10	12	5·32	27	*<0·0001*	1·49	0·557	0·586	0·948
			vcdur	8	63	4	28	−8·47	21·33	*<0·0001*	34·19	<0·001	0·221	0·227
S26 m	12	7	fricdur	101	75	9	9	5·77	17	*<0·0001*	1·12	0·818	0·446	0·133
			vcdur	9	68	5	18	−8·52	6·55	*<0·0001*	12·70	<0·001	0·925	0·141
S27 f	11	11	fricdur	81	61	10	16	3·29	20	0·0035	2·46	0·171	0·555	0·321
			vcdur	5	54	4	26	−6·13	10·60	*<0·0001*	32·88	<0·001	0·063	0·342
S28 m	10	19	fricdur	92	77	14	9	3·42	27	0·0019	2·04	0·188	0·152	0·652
			vcdur	10	46	5	30	−5·02	20·02	*<0·0001*	32·52	<0·001	0·451	0·004
S29 f	12	17	fricdur	112	91	19	13	3·54	27	*0·0014*	2·09	0·172	0·297	0·308
			vcdur	10	48	6	30	−4·97	18·09	*0·0001*	21·20	<0·001	0·649	0·001

	1		2	3	4	5	6	7	8	9	10	11	12	13
speaker	*n* nv	*n* vd	para-meter	M nv	M vd	SD nv	SD vd	t-value	df	p	f-ratio variance	p-variance	p-ND nv	p-ND vd
S30 m	9	15	fricdur	117	87	18	14	4·47	22	*0·0001*	1·52	0·465	0·285	0·935
			vcdur	10	49	3	38	−3·83	14·27	0·0017	166·12	<0·001	0·174	0·012
S31 m	12	14	fricdur	103	76	19	14	4·08	24	*0·0004*	1·97	0·243	0·528	0·824
			vcdur	8	44	4	24	−5·39	13·80	*<0·0001*	37·38	<0·001	0·666	0·109
S32 m	9	7	fricdur	100	76	6	4	8·83	14	*<0·0001*	2·44	0·291	0·955	0·613
			vcdur	5	38	5	29	−2·90	6·28	0·0256	32·51	<0·001	0·013	0·027
S33 f	12	21	fricdur	111	110	17	15	0·24	31	0·8144	1·19	0·701	0·020	0·168
			vcdur	6	15	3	8	−3·95	29·68	*0·0004*	5·13	0·007	0·987	<0·001
S34 f	12	17	fricdur	85	62	11	8	6·25	27	*<0·0001*	1·64	0·356	0·892	0·902
			vcdur	11	36	4	21	−4·55	18·05	*0·0002*	21·59	<0·001	0·563	0·077
S36 m	12	20	fricdur	119	96	16	12	4·51	30	*<0·0001*	1·82	0·240	0·040	0·083
			vcdur	11	80	6	31	−9·37	21·42	*<0·0001*	25·25	<0·001	0·006	0·002
S38 m	11	15	fricdur	97	91	12	9	1·27	24	0·2161	1·89	0·267	0·627	0·048
			vcdur	8	24	3	24	−2·38	14·84	0·0309	44·77	<0·001	0·054	<0·001