GLOTTAL OPENING IN GERMAN OBSTRUENTS

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ABSTRACT

A transillumination study was carried out on the production of stops and fricatives by a native speaker of German. Different parameters involving the glottal opening gesture were measured and evaluated with phonation type and place of articulation as the independent variables. Maximum degree of glottal opening was found to be the most reliable correlate of phonation type. Parameters of oral-laryngeal coordination turned out to be prominent as correlates of place.

1. INTRODUCTION

Compared to our knowledge of glottal opening in the obstruent production of most other Germanic languages, relatively little evidence exists for German [4]. Using the transillumination technique two tasks are addressed in this study. One is to investigate the realization of the opposition between the tense obstruents /p,t,k,f,s/ and the lax obstruents /b,d,g,v,z/ in terms of laryngeal behavior and oral-laryngeal coordination and to compare the results to the realization of related two-way phonation type oppositions in other languages (cf. [3]). A second task is to address how differences in place of articulation are expressed articulatorily. It has been shown that aspiration differences due to place of articulation are associated with the coordination between the location of maximum glottal opening and stop release in English and German [2,4].

2. METHOD

The set of obstruents that can occur in a phonation type opposition in German were produced by a male speaker of German. The obstruents occur in two different contexts, one being intervocalic position preceded by [i] and followed by schwa (e.g. [íp^{h}ə, íbə, ít^{h}ə] etc., which are nonsense words), the other being word-initial position preceded and followed by [i] (e.g. *nie dir* [ni: dɪ̯ɐ] 'never you', *nie Tier* [ni: t^{h}ɪ̯ɐ] 'never animal' etc., which are existing words in German). Recordings were made in two different experimental sessions three weeks apart. Data across sessions were not pooled in the analysis since values for degree of glottal opening are partially specific to factors of the session such as the exact location of the fiberscope. Recordings were made of both the acoustic signal and the transillumination (TI) signal. Both the TI signal and the calculated velocity curve were smoothed to facilitate extraction of the relevant parameters of the glottal opening gesture (Figure 1). Further details of data recording and processing follow the methodology reported in [7].

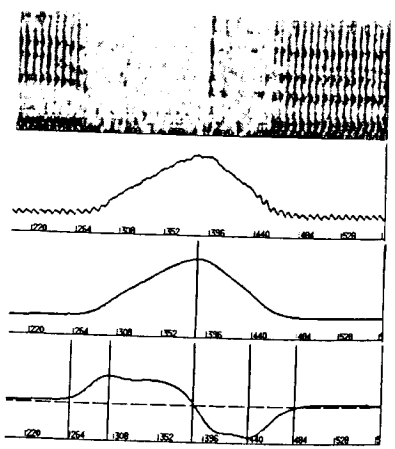

Figure 1. Spectrogram, unsmoothed TI curve, smoothed TI curve, and smoothed velocity curve of one representative token of [íp^{h}ə]. Outmost cursors indicate OG and EG, innermost cursor indicates P.

The following set of parameters was measured. Aspiration duration (Asp) and closure duration (Clos) in stops, and total duration (Total) in fricatives were determined in a spectrogram on the basis of the end (Clos, Total) and beginning (Asp, Total) of F_2 in the adjacent vowel. Maximum degree of glottal opening (Gmax) was measured as the intensity value in the smoothed TI signal at the point in time corresponding to a zero crossing in the velocity curve (P). The remaining parameters are temporal intervals involving the following oral and laryngeal events: onset of consonant (OC), onset of vowel (OV), and stop release (R), as employed in the measurement of Asp, Clos, and Total, as well as the onset of the glottal opening gesture (OG) and its end (EG), and finally the moment of peak glottal opening (P) that is employed for the Gmax measurement. OG and EG were defined as the point in time corresponding to 10% of maximum and minimum velocity, respectively. The interval between OG and EG was taken as the duration of the glottal opening gesture (Gdur).

3. RESULTS

The results are presented in Table 1. The values in each cell of Table 1 are mean values from the measurements of approximately 20 tokens. For many lax fricatives in word-initial position glottal opening was too small for measurement application or absent. This context was therefore not considered for fricatives.

Table 1. Mean values and standard deviations (separated by a slash) of the different parameters (first column) in two contexts (second column), and two experimental sessions (third column) for the stops /p,t,k,b,d,g/ (above) and the fricatives /f,s,v,z/ (below). "P-R", for example, stands for "P minus R". The values are in milliseconds, except for Gmax which is expressed in arbitrary units.

Param.	Ctx.	S.	p	t	k	b	d	g
Asp	í_ə	1	61/9	83/10	73/10	18/2	21/3	32/7
Asp	í_ə	2	49/6	89/8	66/16	16/3	25/4	34/7
Asp	i#_í	1	84/14	93/7	111/14	25/3	34/3	57/9
Asp	i#_í	2	81/13	90/10	104/8	23/5	28/4	48/10
Clos	í_ə	1	106/11	69/7	90/8	87/6	54/5	73/13
Clos	í_ə	2	97/7	67/7	92/9	82/7	54/6	77/11
Clos	i#_í	1	126/13	112/10	112/11	138/10	126/7	122/18
Clos	i#_í	2	117/8	106/6	114/14	114/8	108/10	111/13
Gdur	í_ə	1	202/8	183/11	208/8	100/7	80/8	140/11
Gdur	í_ə	2	188/14	188/8	190/10	90/13	69/8	132/15
Gdur	i#_í	1	237/15	223/11	236/15	161/17	151/10	188/13
Gdur	i#_í	2	213/15	203/14	220/16	117/18	126/19	165/15
Gmax	í_ə	1	-51/ 121	-156/ 104	307/105	-585/44	-572/52	-437/29
Gmax	í_ə	2	-862/142	-907/85	-796/139	-1305/25	-1314/23	-1280/40
Gmax	i#_í	1	-8/189	-122/247	214/303	-628/122	-677/40	-513/38
Gmax	i#_í	2	-842/183	-928/116	-659/189	-1335/24	-1316/30	-1296/16
P-R	í_ə	1	-1/5	18/9	9/7	-1/2	7/5	-7/7
P-R	í_ə	2	-5/4	28/10	12/7	0/4	10/4	-6/9
P-R	i#_í	1	0/5	11/7	17/10	-32/29	-26/19	-33/15
P-R	i#_í	2	-5/6	8/6	12/8	-17/14	-10/12	0/20
OG-OC	í_ə	1	0/5	2/5	-7/5	30/3	21/7	-1/5
OG-OC	í_ə	2	3/5	6/5	7/5	34/7	29/7	7/10
OG-OC	i#_í	1	5/7	5/3	6/11	19/7	23/6	6/9
OG-OC	i#_í	2	7/5	16/10	17/19	31/10	22/8	6/2
P-OC	í_ə	1	104/9	88/5	100/6	85/4	62/7	65/9
P-OC	í_ə	2	91/4	96/7	100/20	83/7	65/7	70/6
P-OC	i#_í	1	125/10	124/7	130/11	105/26	100/18	88/20
P-OC	i#_í	2	111/7	115/7	128/14	97/14	97/14	112/25
P-OV	í_ə	1	-63/6	-64/4	-63/7	-20/3	-13/5	-40/6
P-OV	í_ə	2	-55/4	-61/7	-55/7	-16/5	-14/4	-41/5
P-OV	i#_í	1	-84/12	-81/6	-93/8	-57/27	-60/17	-91/19
P-OV	i#_í	2	-87/13	-82/8	-90/8	-41/16	-40/11	-48/16
EG-OV	í_ə	1	33/7	32/7	36/8	24/3	24/6	31/5

EG-OV	í_ə	2	44/10	37/11	36/9	25/6	18/3	27/7
EG-OV	i#_í	1	30/7	22/3	17/4	17/6	14/3	14/7
EG-OV	i#_í	2	21/7	22/6	17/3	10/4	11/5	10/4

Param.	Ctx.	S.	f	s	v	z
Total	í_ə	1	163/9	183/11	112/13	122/12
Total	í_ə	2	160/8	170/9	106/9	116/13
Gdur	í_ə	1	200/10	218/12	152/73	236/25
Gdur	í_ə	2	195/9	200/11	152/45	222/48
Gmax	í_ə	1	265/185	261/195	-625/35	-555/68
Gmax	í_ə	2	-616/268	-872/98	-1313/41	-1297/51
OG-OC	í_ə	1	-16/7	-12/6	-4/51	-60/20
OG-OC	í_ə	2	-15/6	-7/5	-18/36	-33/29
P-OC	í_ə	1	78/9	87/7	76/28	67/15
P-OC	í_ə	2	74/7	84/7	73/13	67/15
P-OV	í_ə	1	-84/7	-95/9	-36/21	-55/11
P-OV	í_ə	2	-85/7	-85/6	-33/17	-48/13
EG-OV	í_ə	1	20/4	21/4	35/40	53/19
EG-OV	í_ə	2	18/4	21/3	26/32	73/42

One-way ANOVAs were calculated, separately for stops and fricatives and for each context and session, with each of the parameters as the dependent variable. In one set of ANOVAs the independent variable was phonation type (tense, lax), in another set, in which only the tense obstruents were included, the independent variable was place of articulation (labial, alveolar, velar). Not all details of the statistical results can be reported here. Instead the results are presented on a more general level, focusing on the question of the reliability of the parameters across different factors. A given parameter will be considered a maximally reliable correlate of phonation type if tense and lax obstruents differ significantly in this parameter across the factors of context, session, and place of articulation, and if in addition the difference has the same directionality across these factors (e.g. Asp in tense stops always longer than in lax stops). Similarly, reliability for place of articulation is determined with respect to statistical significance and unidirectionality across contexts and sessions. In addition, reliability for stops, that involve three places of articulation, has been further determined on the basis of post-hoc tests (Fisher PLSD) as the occurrence of significant differences in all three possible pairwise comparisons of place.

The parameters Asp, Gdur, Gmax, and P-OC emerge from the statistical analysis as maximally reliable correlates of phonation in stops, since differences between tense and lax stops are significant and unidirectional across place, session, and context. P-OV is lower in reliability, since in one combination of factors (word-initial velar stops of the first session) tense/lax differences are nonsignificant. Likewise, one nonsignificant case is found for the parameter EG-OV, which is the same as for P-OV. P-R shows nonsignificant or heterodirectional instances in two combinations of factors (first and second session of intervocalic labial stops). Next in reliability is OG-OC with two nonsignificant and one heterodirectional case all involving velar stops. Lowest in reliability is Clos that basically shows reliable differences only for intervocalic position. Turning to fricatives, the parameters Total, Gmax, and P-OV are maximally reliable phonation correlates. The remaining parameters come out as basically nonreliable, since in two out of four possible combinations of place and session tense/lax differences are nonsignificant or counter to the dominant directionality. Evaluating the complete set of obstruents, the single parameter that is maximally reliable across stops and fricatives is Gmax. Thus tense obstruents are reliably produced with a larger maximum glottal opening than lax obstruents in German according to the present results.

Evaluating place of articulation for stops, none of the parameters is a maximally reliable correlate in the sense defined above. Most reliability is achieved by Asp and P-R on the one hand, and Clos and Gmax on the other. For Asp and P-R results are significant in all conditions, but differ in directionality across contexts. Clos and Gmax are nonsignificant for certain place comparisons, but are unidirectional throughout. The other parameters are less reliable, since they involve several nonsignificant cases and reversals of directionality. Among fricatives, Total and P-OC is maximally reliable. The rest of the parameters are of lower reliability, because each of them is significant in only one session, although all parameters are unidirectional across sessions.

4. DISCUSSION

The results show that the tense obstruents /p,t,k,f,s/ of German are produced with a significantly larger maximum degree of glottal opening than the lax obstruents /b,d,g,v,z/. German, like many other Germanic languages (but not Dutch) distinguishes tense from lax stops in terms of aspiration. Assuming that aspiration is to a large extent caused by a widely opened glottis [5], it is expected correctly that tense stops in German show a much wider opened glottis than lax ones, which is also reported for other aspiration-based languages (cf. [3] for references). Other than the degree of glottal opening, aspirated and unaspirated stops differ also in terms of oral-laryngeal coordination, most strikingly in terms of P-OC. The relation between this parameter and aspiration has also been shown for Swedish [6], independent of the fact that aspiration investigated in [6] was allophonic (depending on stress), whereas it is phonemic (expressing the tense/lax opposition) here.

The question arises whether the small glottal opening found for most of the lax obstruents is produced actively, as claimed by some authors for Danish and Icelandic (cf. [3]), or whether it results passively from an increase in oral air pressure [1]. The passive account is supported by the fact that lax fricatives, which are expected to have lower oral air pressure than lax stops, have been produced more often completely lacking glottal opening than lax stops in this study.

This study can confirm earlier results for German [4] and English [2] that in the articulatory expression of place of articulation factors of oral-laryngeal coordination, most specifically P-R, are of particular importance. A comparison of the parameters Asp and P-R in stops is revealing in this respect. For both parameters the directionality is vel. > alv. > lab. word-initially and alv. > vel.> lab. intervocalically, suggesting a close relationship between P-R and Asp in the expression of place of articulation.

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