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Compensatory articulations in a case of congenital aglossia

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Abstract
This paper examines the articulatory and phonatory strategies used by a German female born without a tongue. Analysis concentrates on the phonetic correlates of dorsal plosives. The speaker uses two main strategies. In word list material, closure for initial /k, g/ is produced using a combination of the uvula, floor of the mouth and adduction of the glossopalatal arches. In other environments, closure is made at the glottis. The glottal strategy is shown to be consistently different from the junctural glottalization used at vowel onset.

Keywords: *Congenital aglossia, hypoglossia-hypodactylia syndrome, compensatory articulation, glottalization*

Introduction

Congenital aglossia is an extremely rare condition. De Jussieu (1718) is attributed with first documenting a case of hypoglossia in a 15-year-old Portuguese girl. Since then less than 50 further cases of hypoglossia and aglossia have been reported in the literature (Weingarten, Walner, & Holinger, 1993; Thorp, de Waal, & Prescott, 2003). From the point of view of speech development congenital aglossia or hypoglossia represents a special case of tongue loss. In contrast to the loss of tongue through illness or accident later in life, phonetic and linguistic development has gone hand-in-hand with, and may have influenced to some extent, orofacial development. It is of interest to examine strategies used to approximate acoustically and auditorily the patterns normally produced with the tongue by a speaker lacking what is arguably the most flexible and versatile component of the speech production apparatus. It has been found that the absence of a tongue or the presence of only a small rudimentary tongue may be compensated for by hypertrophy of the floor of the mouth (Weingarten et al., 1993; Yasuda, Kitai, Fujii, Murakami, & Takada, 2003), or in the case we report on here, by overdevelopment of the glossopalatal arches.

While there is a wealth of literature documenting compensatory speech patterns and therapeutic strategies following removal of part or all of the tongue and measures designed at reconstructing some kind of lingual replacement (e.g. Skelly, 1973; Allison et al., 1987;

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Savariaux, Perrier, Pape, & Lebeau, 2001), there are almost no studies describing in detail the speech of subjects with congenital aglossia and hypoglossia. References to speech competence of older subjects is generally retricted to little more than two or three sentences. Consistent in all these reports, however, is that ''[s]peech is surprisingly good'' (Gorlin, Cohen, & Levin, 1990, p. 672). Indeed, the 15-year-old described by de Jussieu (1718) was said to speak ''avec la plus grande netteté'' (reported in Bouchut, 1855, p. 433). In a case of a 6-year-old with extreme hypoglossia, Yasuda et al. (2003) state that ''[t]here was no speech problem in his daily life''. Likewise, Goto, Tanaka, and Iizuka (1991, p. 13) describe a 15-year-old boy with congenital aglossia who could pronounce the vowels relatively well by using the floor of the mouth instead of the tongue. Although consonants, which require the use of the tongue tip, were not very clear, conversation was satisfactory. Allison et al. (1987) compare the adaptive mechanisms adopted by patients following tongue and jaw surgery and reconstruction with the speech of a female subject with uncorrected congenital aglossia, who is considered to have almost normal speech (Allison et al. 1987, p. 420). Although it must be said that the use of normal is subsequently qualified by describing the subject's speech as more rapid than normal, clipped and staccatic with use of excessive jaw movements, lack of solid closure and premature release of consonants. In the absence of any more detailed phonetic analysis, we can only speculate about the true quality of the speech being produced by these subjects.

To the best of our knowledge, in only one case of congenital aglossia has any detailed phonetic analysis been published. This was done in the case of a 29-year-old female (Ernst & Meinhold, 1964; Kurka & Meinhold, 1965). The main goal of the present study is to develop and augment their description with an analysis of the compensatory strategies used by this speaker for the production of dorsal consonants in German. A further aim of this paper is to make the recording of this speaker more widely available for research and teaching purposes.[1]

We begin by summarizing the main clinical and phonetic findings of Ernst and Meinhold (1964) and Kurka and Meinhold (1965) since they are not likely to be readily available to many readers. We then describe the compensatory articulations used for dorsal consonants, concentrating on auditory phonetic and spectrographic study of the glottal strategies used by the speaker, which only find brief mention in the earlier studies.

Speech material

One of the most fortunate legacies of the case described in Ernst and Meinhold (1964) and Kurka and Meinhold (1965) is an analog tape-recording made of the subject reading a word list and, directly afterwards, a short prose passage. The word list consists of 38 monosyllabic and polysyllabic words with representative coverage of the German vowel system and consonants in different structural positions. The prose passage was a short story (Brecht: ''Die zwei Söhne''). All the elicitation materials are to be found in the Appendix.

The original analog recording was transferred to computer digitizing at a sampling rate of 16kHz and an amplitude resolution of 16 bits using CSL (Kay Elemetrics).

Speaker and earlier findings

Clinical findings

The subject is a 29-year-old female. She exhibited a number of anomalies besides aglossia including strabismus and syndactylia, and is more accurately described under present

classification as suffering from hypoglossia-hypodactylia syndrome (Gorlin et al., 1990, p. 672). The findings of dental, roentgenological, ophthalmological and otological examinations are described in detail in Ernst and Meinhold (1964). Here we will restrict ourselves here to a description of the details relevant to speech production.

Apparent from the profile and frontal view in Figure 1 are micrognathia and microgenia, and crucial for articulatory purposes, the position of the bottom lip with respect to the roof of the mouth. The mandibular arch is reduced and its alveolar process is very flat back to the region of the second molar so that the transition from the vestibulum to the cavum oris is flat. The dental status is as follows:

7	6		4	3	2	1		2	3	4	5	6	7
7	6											6	7

The subject reports having lost a number of teeth from her bottom jaw. X-rays show no retained or displaced teeth. The upper jaw is also compressed, so that there is crowding despite hypodontia. A mucous cleft about 2cm in length is also present. The most significant intraoral finding is the absence of tongue and the oral diaphragm so that one looks directly into the mesopharynx when the mouth is open (see Figure 2). The glossopalatal arches are hypertrophied, inserting directly at the level of the shortened mandibular arch. The absence of the tongue is also clearly visible on a lateral cephalogram. Only in the region of the tongue root is there a suggestion of a tongue rudiment.

Compensatory articulations

Many of the compensatory articulations used by the speaker are reported in Ernst and Meinhold (1964) and Kurka and Meinhold (1965). In particular, they describe

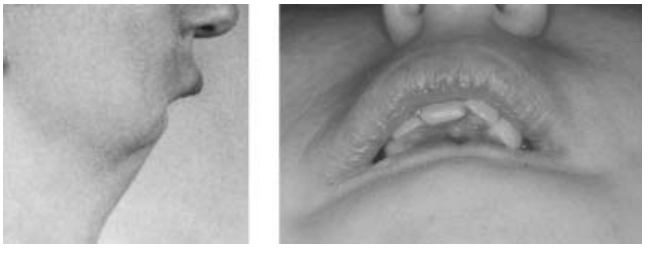


Figure 1. Profile of speaker and view from below of typical labio-alveolar stricture of close approximation.

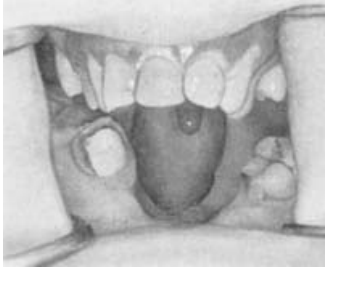


Figure 2. Intraoral photograph of speaker showing absence of tongue, compressed top jaw, loss of teeth in bottom jaw and insertion of glossopalatal arches.

articulations ranging from labio-prepalatal to labio-dental which were facilitated by the small mandible. The exact location of the bottom lip in the dental to pre-palatal region together with stricture size and method of release enabled the speaker to produce the correlates of many German consonants ranging from bilabial /p, b/ to the palatal allophone of /x/: [ç]. Detailed descriptions of the strategies used for the different consonants are given, each with reference to examples which can be found in the recording. Many articulations are also illustrated with photographs. The articulations involving the bottom lip are summarized here:

/p, b, m/ are produced labiodentally with the strong contraction of the bottom lip forming a stricture of complete closure behind the top teeth (see Figure 3a). The auditory impression is however more labial than dental. (*Palast, Bäcker, Diamant*)

/t, d, n/ are produced by the bottom lip making closure with the alveolar ridge (see Figure 3b). By contrast to /p, b, m/ the bottom lip does not make contact with the top front teeth. (*Tante, Dackel*)

/f/ is produced by the bottom lip making median closure at the alveolar ridge. Turbulent airflow escapes laterally. (*Fenster*)

/s, z/ is produced by the bottom lip making a stricture of close approximation at the alveolar ridge (see Figure 3c). The lips are spread slightly. The friction is audibly more strident than for /f/, but less than would be found for a normal linguo-alveolar sibilant. (*Palast, Sohn*)

/ʃ/ is produced with labiodental contact. The bottom lip is drawn to the right and the top lip is protruded (see Figure 3d). Turbulent airflow escapes between the top teeth and between the top teeth and inside of the cheek. (*Schwalbe*)

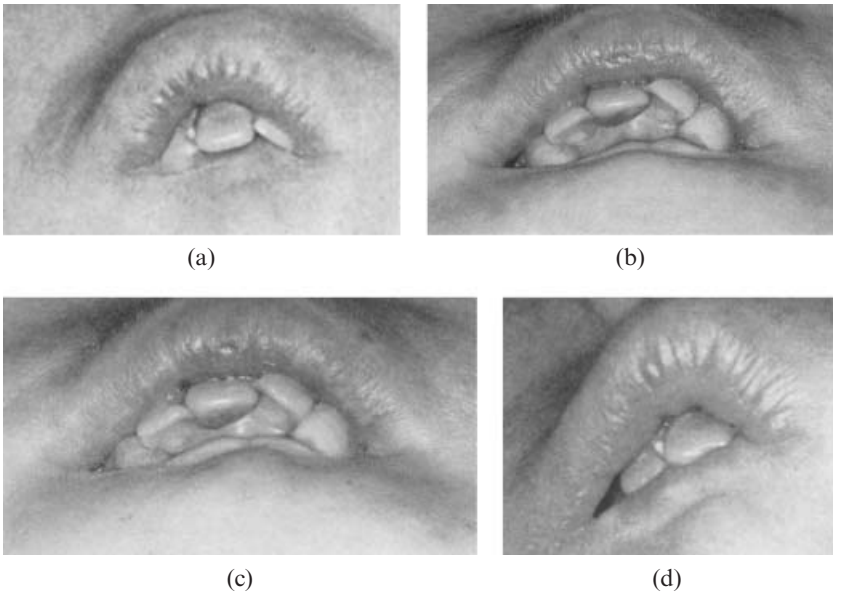


Figure 3. Photographs of compensatory articulations involving the bottom lip: (a) labio-dental closure for /p, b, m/; (b) labio-alveolar closure for /t, d, n/; (c) labio-alveolar stricture of close approximation for /s/; (d) lateral labio-dental stricture of close approximation for /ʃ/.

/x/ (palatal correlate) is produced by the labio-prepalatal stricture of close approximation (see Figure 1). The stricture is slightly larger and made further back than that for /s/. (*Weich*)

/l/ is produced with a labio-alveolar stricture of open approximation (not lateral). (*Palast*)

The dorsal consonants /k, g/ were described as being produced by the speaker drawing together the glossopalatal arches, which together with the uvula and the floor of the mouth form a stricture of complete oral closure. We will now move on to develop and refine this analysis.

Compensatory strategies for dorsal consonants

A commonly reported strategy used by subjects who are unable to block the passage of air through the nose, and thus unable to create a sufficient build-up of pressure behind an oral stricture of complete closure in a plosive articulation, is to compensate with closure at the glottis (e.g. Bzoch, 1965; Chapman, 1993; Pamplona, Ysunza, González, Ramírez, & Patiño, 2000; D'Antonio, Scherer, Miller, Kalbfleisch, & Bartley, 2001). In many cases, descriptions of this phenomenon give the impression that it leads to a neutralization of what otherwise would be a six-term plosive system (e.g. Hutters & Brønsted, 1986; Howard, 2004). However, Kelly and Local (1989) show in their description of the compensatory glottal articulations by one young speaker, that although superficially this speaker was only producing a glottal stop for all final plosives, she was productively maintaining a six-way contrast by using glottal stops with and without audible release together with different accompanying lingual and labial configurations. Work on covert contrast (Scobbie, Gibbon, Hardcastle, & Fletcher, 1998, 2001) has shown that children may be realizing phonological contrasts using phonetic differences which are detectable instrumentally, but which cannot be perceived by the analyst.

Glottal compensation is one of the strategies the speaker in the present study also uses for what would otherwise be dorsal plosives. The question of neutralization with plosives at other places of articulation does not arise since these are realized labio-tectally. However, glottalization in German is a correlate of vowel onset. The question then arises as to whether the speaker phonetically differentiates junctural glottalization and glottal compensation.

Oral strategy for dorsal consonants

The oral strategy described by Kurka and Meinhold (1965) above is consistently used in the word list material at word onset regardless of stress placement, e.g. '*Gatter* (''enclosure''), *Ge'hör* (''hearing''). For the fortis onset, the plosive release is also followed by aspiration, not present in the lenis onset. Figure 4 contains sound pressure waveform and spectrogram of the words *Kabel* (''cable'') and *Gatter* (''enclosure'') from the word list material. Letters have been positioned close to the point of release for the initial plosives in each word. The auditory impression of this plosive in terms of a standard categorization is post-velar to uvular. The impression of a more posterior articulation is more marked preceding a front vowel, e.g. *Käfig* (''cage''), since there is none of the coarticulatory fronting usually found in such positions in German.

Judging by its distribution in the data, the oral strategy would seem not only to be restricted to word-initial position, but also to be stylistically privileged, occurring primarily in the word list material. Only one word (*glaubte* ''believed'') in the prose text has the oral

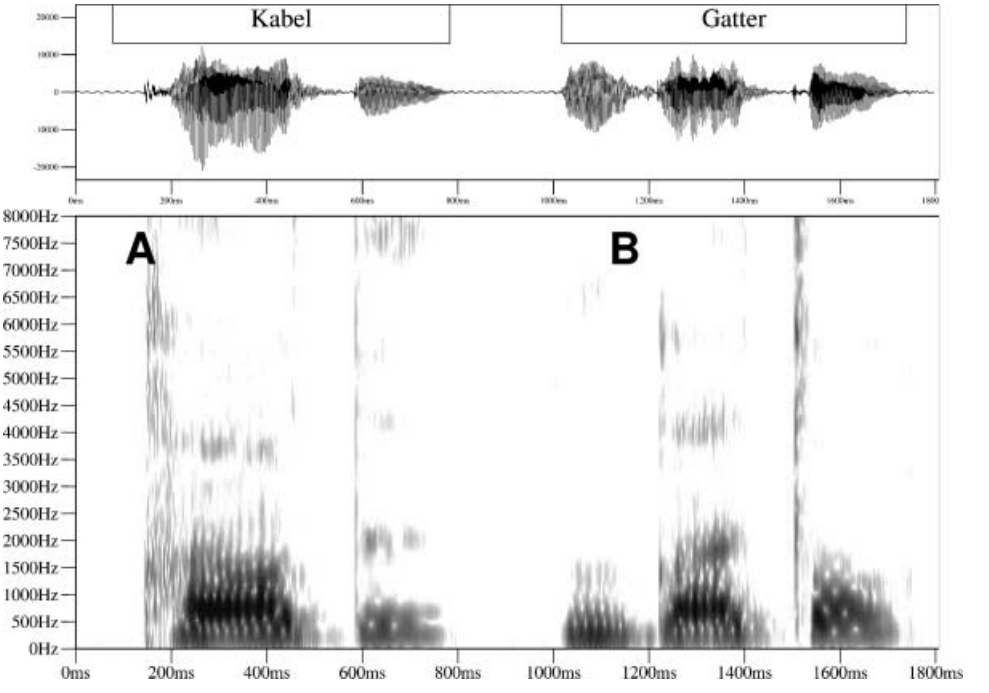


Figure 4. Sound pressure waveform and spectrogram of the words *Kabel* (''cable'') and *Gatter* (''enclosure'') from the word list material. The word *Gatter* begins with a voiced nasal which is possibly due to hyperarticulation of voicing for the lenis plosive.

closure in the initial cluster. In all remaining contexts the speaker uses a glottal strategy, even, we will argue, in initial /kr-/ and /gr-/ clusters where the auditory impression of the plosive portion of the cluster may initially appear to be oral.

Glottal strategy for dorsal consonants

At first sight and hearing, the glottal strategy is unremarkable: the speaker makes a compensatory stop closure at the glottis. On closer examination, however, and in particular in comparison with the glottal exponents of juncture described above, the glottal strategy is fascinating. Figure 5 contains the sound pressure waveform and spectrogram of the word *Bäcker* (''baker'') produced in the word list material. At A there is a stretch of acoustic silence lasting approximately 120ms, auditorily glottal closure. This is preceded by two periods of voicing with relatively long period duration indicative of a short stretch of creak. However, the auditory impression following glottal closure, backed up by the acoustic record, is of immediate onset of modal voice. Weak spectral energy visible below 1kHz over the first portion of the glottal stop suggests that the closure is somewhat ''leaky''. This is most clearly visible during the glottal closure in Figure 7. Examination of other places in the utterance do not suggest that it is a recording artefact such as echo.

This word list pattern continues in the text. Figure 6 contains the excerpt *einige Tage darauf* (''several days later''). Of interest here is the compensatory glottal activity at A and B. In both cases we can see the acoustic product of glottal closure lasting more than 100ms. This is preceded by a short stretch of creak. The following vocalic portions are extremely

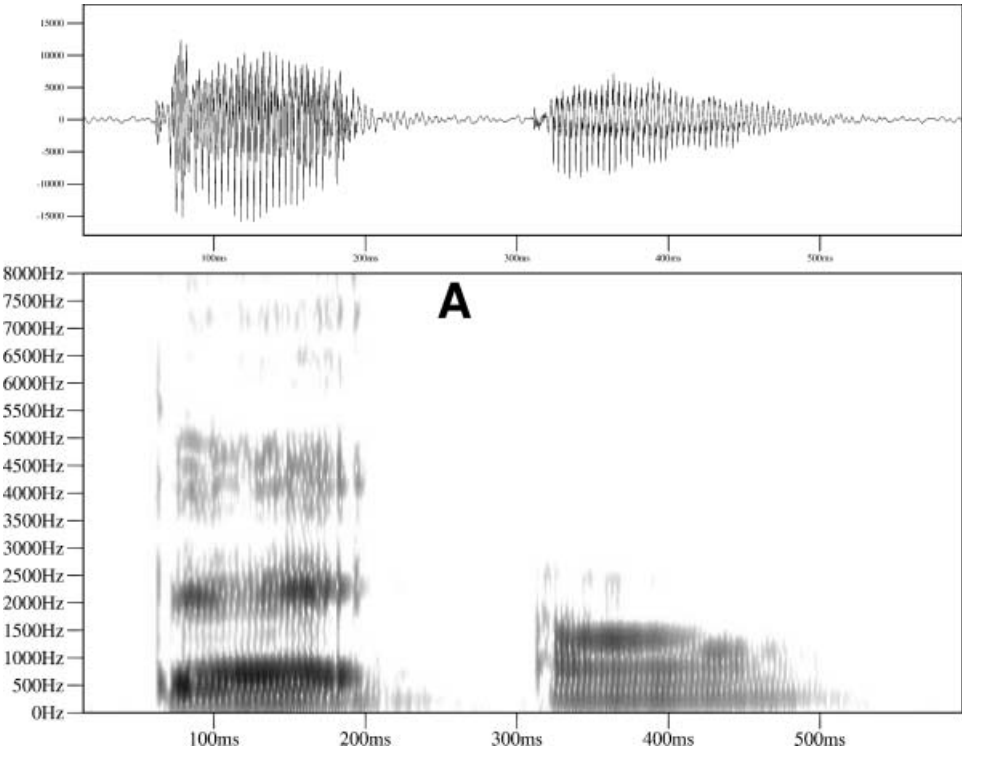


Figure 5. Sound pressure waveform and spectrogram of the word *Bäcker* (''baker'') from the word list material.

short and weakly voiced before the oral closure for the alveolar plosives which follow in each case. It is possible that there is a trade-off between the length of consonant and vowel portions here in order to maintain the rhythmic integrity.

Glottal closure with a mean duration of 100ms characterizes the other examples of compensatory glottal stops in the text, ranging from 135ms in stressed onset position to below 80ms in /r/-clusters.

Identifying possible fortis-lenis differences in the glottal activity is complicated by the neutralization of the fortis-lenis contrast in certain positions. In common with other varieties of central German, initial plosive clusters with /r/ and /l/ tend to be fortis, creating homophonous utterances in pairs such as *krieche* (''crawled'') and *Grieche* (''Greek''). Furthermore, intervocalically, following a stressed syllable, the fortis-lenis distinction can also be neutralized. The patterns found in potential /kr-/ and /gr-/ clusters in our speaker seem to confirm this. Likewise, in the word list material, while there are measurable differences in the intensity of the vowels and in the length of glottal closure intervocalically in the words *Bäcker* (''baker'') and *Bagger* (''digger'') there is no evidence that these differences are anything more than the normal variation.

In stressed onset position however, fortis onsets are marked by aspiration following glottal closure. This is illustrated by the token of the word *erkannte* (''recognized'') shown in Figure 7. At around 82350ms the spectrogram shows the typical acoustic correlates of aspiration with cavity turbulence: energy concentration at the higher formant frequencies (here F2, F3), but with little or no visible energy below 1kHz, indicating a lack of voicing.

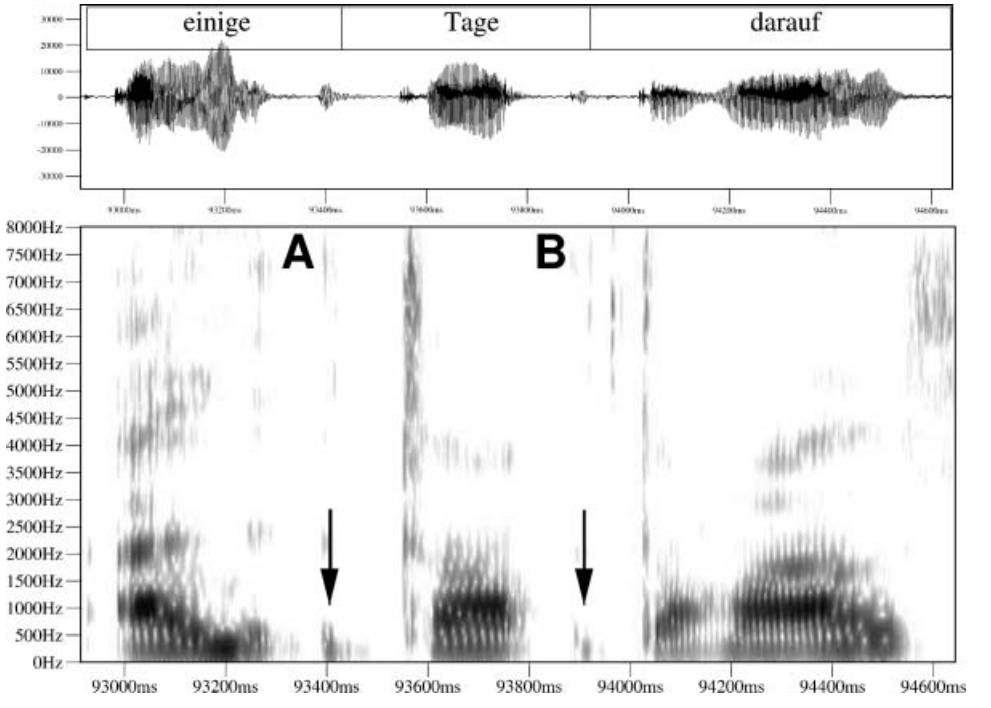


Figure 6. Sound pressure waveform and spectrogram of the excerpt *einige Tage darauf* (“several days later”) from the text.

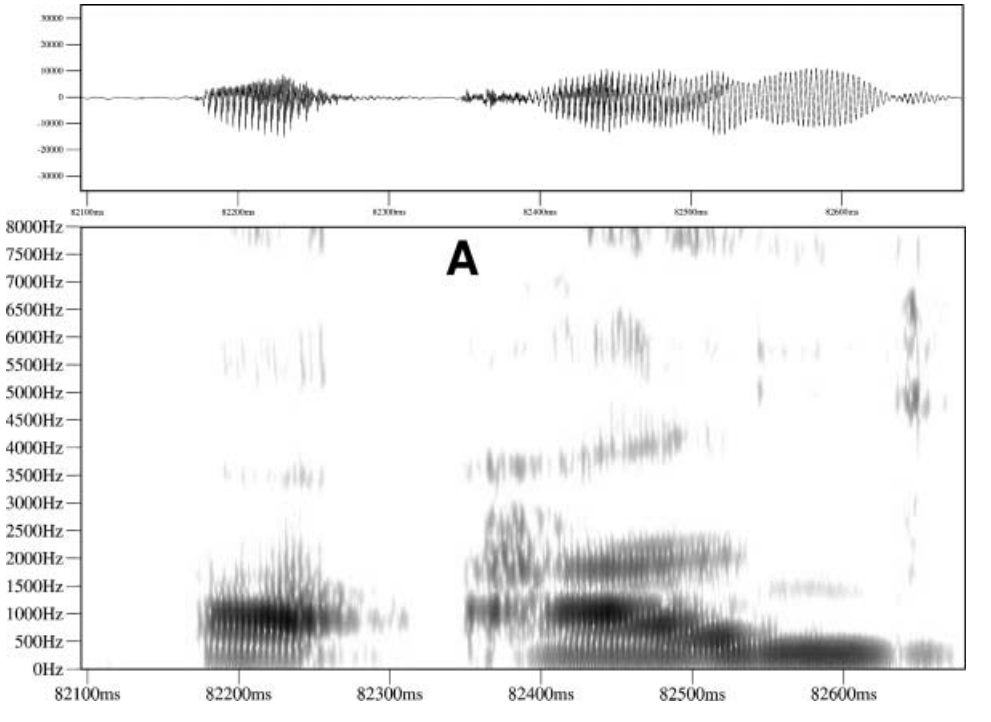


Figure 7. Sound pressure waveform and spectrogram of the excerpt *erkannte* (“recognized”) from the text.

Glottal exponents of juncture

A well-documented feature of German is the presence of glottalization accompanying vowel-initial syllables. Many studies in recent years have however shown that the typical textbook description of the glottal stop at the beginning of such syllables in normal speech is a gross oversimplification. Instead, a glottal stop is just one possible component of juncture (Kohler, 1994; Rodgers, 2000). Often it is creaky phonation alone which is likely to be found utterance internally, and in unstressed syllables with close vowel qualities, observable non-modal phonation may be absent.[2]

The short excerpt in Figure 8 illustrates the typical range of variation which may be found in a single read utterance. The figure contains the sound pressure wave and spectrogram of *Es ist acht Uhr* (''It's 8 o'clock'') read by a young female speaker of North German. The letters A–D indicate the beginnings of V-initial syllables. At A the pronoun *es* coincides with utterance onset. The auditory impression as well as the acoustic record indicate that the vocalic portion begins with a closed glottis and is followed by a short stretch of creak. The auditory impression of the half-close vocalic portion of the unstressed copula *ist* at B together with the regularity of the quasi-periodic signal suggest no signs of glottalization. By contrast, at C, *acht*, the stretch of acoustic silence indicates a relatively long glottal closure which releases ''cleanly'' into modal voice. Finally, at D, the vocalic portion of *Uhr* begins with a few periods of low frequency creak.

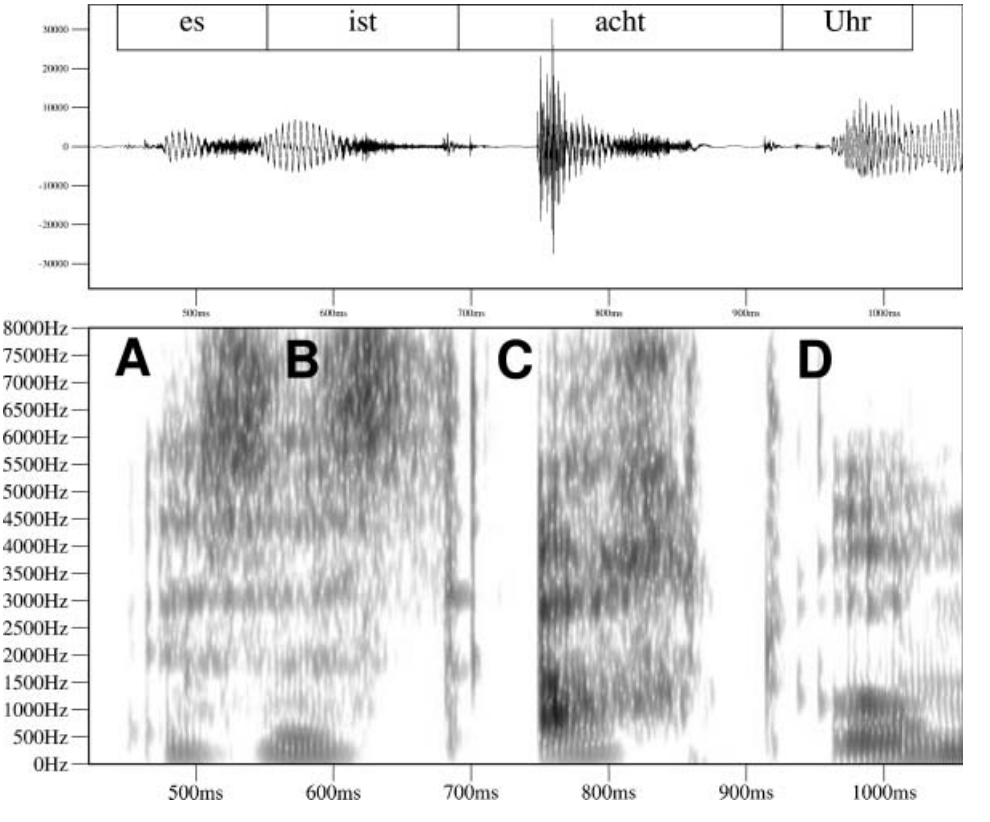


Figure 8. Sound pressure waveform and spectrogram of the excerpt *Es ist acht Uhr* (''It's 8 o'clock'') spoken by a young female speaker of North German. The letters A–D identify beginnings of V-initial syllables.

Our speaker exhibits similar patterns of glottalization, ranging from absence of glottalization in the acoustic record to relatively long periods of glottal closure and creak. Examples illustrating the range of correlates are presented in Figure 5, which contains the sound pressure waves and spectrograms of (a) *als sie ihn ansprach* (''when she spoke to him'') and (b) *dass es einer* (''that it one'').

At the beginning of the open vocalic portion of post-pausal *als* at A in Figure 9a, the acoustic record shows acoustic silence followed by two periods of relatively long duration and low amplitude indicative of glottal closure followed by creak. Similarly at B, the lower amplitude and lower frequency of the quasi- periodic signal lasting approximately 100ms indicates a stretch of creak expounding juncture in the vowel-vowel sequence in *sie ihn*. In common with other such longer stretches of creaky voice, voicing is low amplitude and irregular in frequency with the fundamental frequency ranging from below 100Hz to approximately an octave below that of her regular voicing, i.e. about 140Hz. In C, the vocalic portion at the beginning of *an(sprach)* begins with low frequency, low amplitude creak, becoming stronger and more regular. In Figure 9b, the regularity of quasi-periodic signal in the acoustic record suggests that no glottalization is present at A in the vocalic portion of unstressed *es*. At the beginning of the vocalic portion of the stressed pronoun *einer* at B there is a stretch of acoustic silence lasting about 100ms followed by two or three periods of relatively long duration, which together are commensurate with the auditory impression of glottal closure followed by a short stretch of creak.

Comparison of glottal compensation for dorsals and juncture

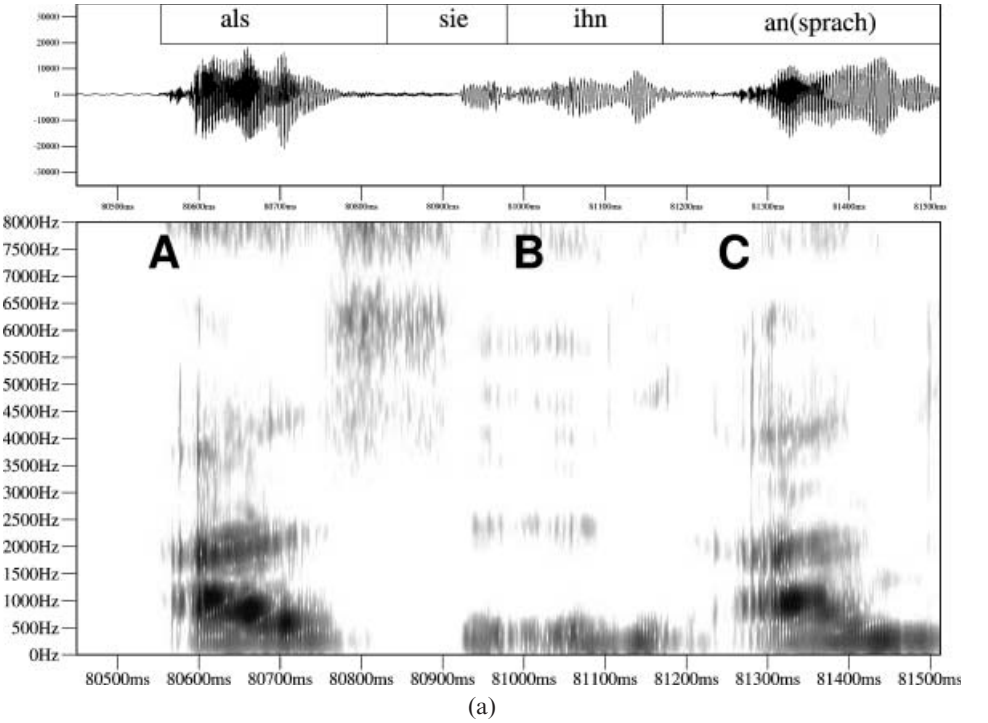
What should have become very clear from this description is that the glottal correlates of juncture are different from those of the glottal activity which the speaker uses to compensate for dorsal closure in a number of ways. The compensatory glottal activity for the dorsals is characterized by the following:

1. Relatively long glottal closure.
2. Creak is not a possible alternant to glottal closure.
3. Creak precedes but does not follow glottal closure.

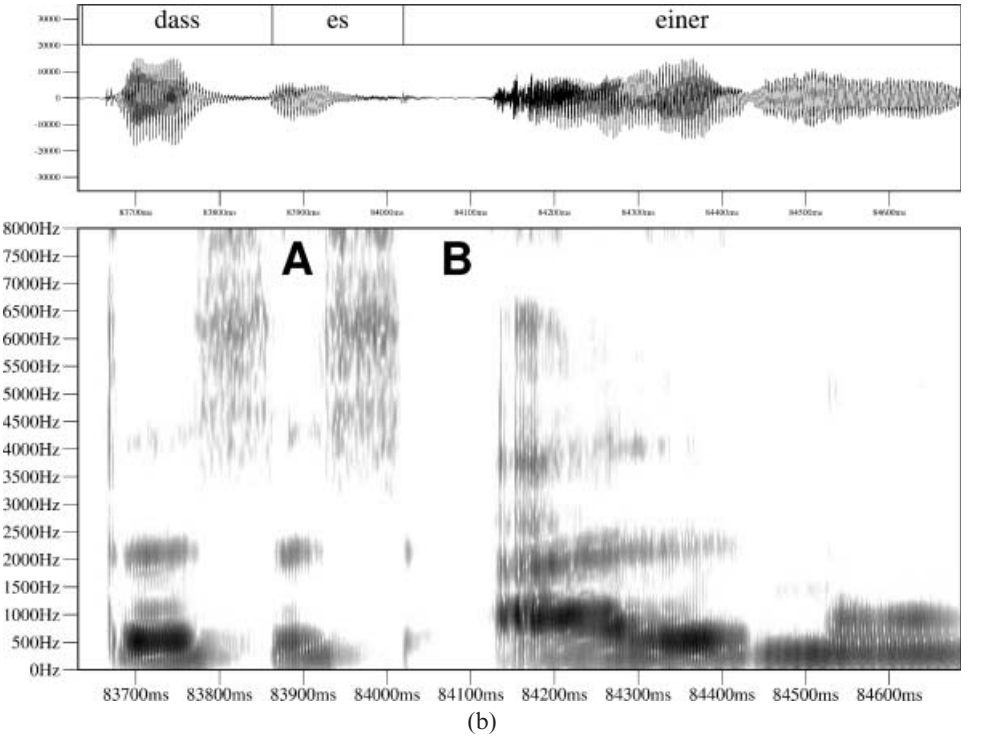
These differences are perhaps most saliently illustrated by the excerpt *zu Ende ging* (''ended'') displayed in Figure 10. The quasi-periodic stretch lasting approximately 100ms in the acoustic record at A is lower in frequency and weaker in amplitude in comparison with immediately adjacent stretches, indicating the typical creaky voice we have seen in vowel-vowel sequences above. This stands in stark contrast to the acoustic correlate of glottal closure at the onset of *ging* at B, which also lasts about 100ms.

Discussion

In German, the glottal stop and creaky voice are phonetic correlates of vocalic juncture. Creaky voice is often treated as an inevitable accompaniment to a glottal stop and consequently as a natural replacement of a glottal stop, presumably requiring less articulatory effort. However, the consistent and systematic differentiation of glottal activity made by the speaker in this study indicates that we may have to question certain assumptions about the link between glottal stop and creaky voice in normal speakers. The speaker's glottal compensation for dorsal consonants is highly constrained, whereas her junctural glottalization exhibits the same wide range of variability as that shown by other



(a)



(b)

Figure 9. Sound pressure waveforms and spectrograms of the excerpts (a) *als sie ihn an(sprach)* (“when she spoke to him”) und (b) *dass es einer* (“that it one”). The letters illustrate places of juncture with V-initial syllables.

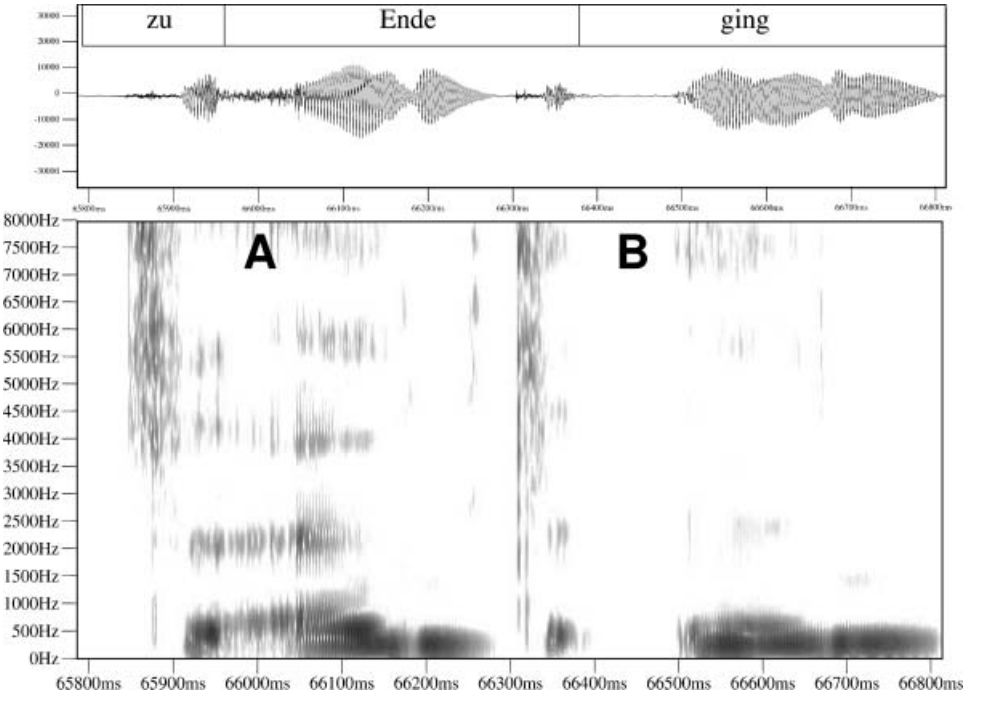


Figure 10. Sound pressure waveform and spectrogram of the excerpt *zu Ende ging* (''ended'') from the text.

speakers of German. One way of interpreting these findings is that the variability is in itself just as controllable as the tightly defined glottal correlates of dorsality.

One of the implications of the detailed impressionistic analysis of the glottal stops made in Kelly and Local's (1989) case study, or in the detailed acoustic analysis of the fortis-lenis contrast reported in Scobbie et al. (1998, 2001), is that a speaker may be producing a larger range of phonological distinctions than a more superficial auditory (or even acoustic) analysis might at first suggest. The findings of this study support this and we might expect from this that many purported neutralizations arising from compensatory glottal articulations in cleft palate speech may just be a product of observation lacking the necessary detail rather than a true reflection of a speaker's phonology.

Acknowledgements

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Notes

1. The audio file and a word-label file in WaveSurfer format can be found at following URL: http://www.uni-jena.de/~x1siad/audio_exx.html
2. This formulation is perhaps slightly over careful, but from some of the examples which Rodgers (2000) presents, it is clear that in certain V-V sequences the only observable correlate of juncture is a slight dip in intensity which maybe a move towards non-modal voicing.

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Appendix

Word list

1	Palast	11	Diele	21	Sinn	31	weich
2	Palme	12	Kabel	22	Saal	32	dich
3	Bäcker	13	Käfig	23	Sohn	33	Fläche
4	Bagger	14	Koks	24	Nase	34	Fenster
5	Tisch	15	Gatter	25	Hase	35	fordern
6	Talent	16	Gebäck	26	diese	36	Wade
7	Tante	17	Gehör	27	Schneeball	37	werfen
8	Taufpate	18	Zeit	28	Frist	38	Wurzel
9	Dackel	19	Zauber	29	Schwalbe		
10	Diamant	20	Zimmer	30	Schnecken		

Text (Bertolt Brecht ''Die zwei Söhne'')

Eine Bäuerin im Thüringischen träumte im Januar 1945, als der Hitlerkrieg zu Ende ging, dass ihr Sohn im Feld sie rief, und schlaftrunken auf den Hof hinausgehend, glaubte sie ihren Sohn an der Pumpe zu sehen, trinkend. Als sie ihn ansprach, erkannte sie, dass es einer der jungen russischen Kriegsgefangenen war, die auf dem Hof Zwangsarbeit verrichteten. Einige Tage darauf hatte sie ein merkwürdiges Erlebnis. Sie brachte den Gefangenen ihr Essen in ein nahes Gehölz, wo sie Baumstümpfe auszugraben hatten. Im Weggehen sah sie über die Schulter zurück denselben jungen Kriegsgefangenen, übrigens einen kranklichen Menschen, das Gesicht nach dem Blechtopf wenden, den ihm jemand mit der Suppe reichte.