Interaction of Timing and Pitch in Cross-Varietal Data

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Abstract

In the present study directly comparable speech data produced by German and Swiss German speakers were examined to investigate interdependencies between pitch accent realisations and timing. An auditory and acoustic analysis was carried out to explore the interaction of measured and perceived duration and excursion of f0-movement.

1. Introduction

Speech prosody has previously been shown to operate on different linguistic, para-linguistic and extra-linguistic levels of speech. Prosodic features were shown to distinguish between sentence types, to express different attitudes and emotions, and they were found to provide information about the speaker's regional, national, social etc. background. However, research has mainly been concerned with the observation of pitch and its acoustic correlate f0. The interaction of prosodic features, their interdependency and their interaction with the segmental level has received less attention (e.g. Chafe, 2000; Liberman & Pierrehumbert, 1984; Ladd, Mennen & Schepman, 2000). Furthermore, only recently research in prosody takes into account that specific acoustic manifestations of utterances in the prosodic domain might be the product of biophysical constrains allowing only insights into the phonetic surface realisation of underlying functional units; a fact which has been demonstrated for the segmental level in the allophonic variation of consonants and vowels using various frameworks and theoretical approaches. For the prosodic level, such relationships have not been addressed to the same extent.

The present study provides preliminary results of an analysis investigating an interaction between specific f0-patterns and the duration of segmental phonetic material using cross-varietal speech data from German, spoken in Germany and Switzerland (Ulbrich, 2005).

The two German standard varieties are well known to differ significantly on the segmental level, especially with respect to the realisation of vowel quality and quantity (Keller, 1961). Furthermore, they were recently shown to differ substantially on the prosodic level.

In a comprehensive study investigating prosodic features in read, semi-spontaneous and spontaneous speech, produced by news readers of the German standard varieties, differences were found in speech rate, number and length of pauses, f0-declination, and in the realisation of pitch accent patterns amongst others (Ulbrich, 2005, 2006). Crucially, these standard varieties were found to differ significantly in number and phonetic realisation of rising and falling pitch patterns.

The present paper aims to provide evidence that those differences may be due to differences in durational (timing) aspects of speech. Swiss German speakers were previously found to produce more rising than falling pitch patterns whereas German speakers produced a relatively equal number of rising and falling pitch accent patterns. Additionally, Swiss German speakers show – apart from qualitative differences in the vowel realisation – differences in the timing of accented syllables. Acoustic measurements confirmed a perceptual impression of larger quantitative differences between accented and unaccented syllables in Swiss German compared to German data (Ulbrich, 2005). In the present study cross-varietal data were examined to investigate the interaction between the distribution and the number of rising and falling pitch patterns on the one hand and lengthening on the other hand to account for cross-varietal differences in the realisation of pitch accent patterns.

The second part of the analysis deals with the interaction of segmental duration, voicing of the segmental phonetic material and the realisation of pitch accents within and across the two groups of speakers. German speakers were previously found to produce accented syllables shorter in duration and with a smaller f0-excursion than Swiss German speakers (Ulbrich, 2005 & 2006). Swiss German speakers were found to produce rising pitch patterns in the majority with an upwards glide within the accented syllable. The analysis of those differences in the phonetic realisation of pitch patterns seeks evidence that glides are directly related to the duration of the segmental material within the accented syllable.

2. Previous findings

The following section summarizes previous results found in a larger cross-varietal comparison of the German, Swiss German and Austrian German standard varieties. It focuses on the comparison of the German and the Swiss German standard varieties relevant to the present paper and reports the results found in the auditory and the acoustic analysis.

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2.1. Previous results of the auditory analysis

Findings of the auditory analysis result from a number of perception tests and a prosodic transcription.

- The perception tests were carried out with different groups of control listeners. The participants had varying levels of expertise. The perception tests were mainly carried out to evaluate the prosodic characteristics previously claimed to distinguish the two standard varieties (Meyer, 1989; Panizzolo, 1982; Stock, 2000). The perceptual evaluation of specific prosodic features (e.g. pitch range, pitch movement, pitch excursion, articulation and speech rate, number and duration of pauses etc.) took place on the basis of one news message and a part of a fairytale read by 10 news readers per variety.
- The prosodic transcription of the entire read speech corpus, containing 11 read news messages and the complete fairytale "Little red riding hood" was carried out by four trained phoneticians.

Relevant to the present study were the following results of the auditory analysis (for a comprehensive and more detailed documentation of the auditory analyses see Ulbrich, 2005):

- The quantitative difference between accented and unaccented syllables is larger in utterance produced by Swiss German speakers compared to German speakers (see Ulbrich, 2005:128).
- Swiss German speakers produce more rising pitch accents whereas German speakers produce more falling pitch patterns (see Ulbrich, 2005:130).
- The rising pitch patterns are frequently produced with a perceptually significant upwards glide by the Swiss German speakers leading to the auditory impression of a larger pitch excursion on the accented syllable compared to the German speakers.

2.2. Previous results of the acoustic analysis

The acoustic analysis confirmed the results of the auditory analysis to a great extent.

Duration measurements of the periodic portion in segmental-phonetically identical syllables showed that Swiss German speakers produced a significantly larger quantitative difference between accented and unaccented syllables which is due to reduction in unaccented syllable accompanied by lengthening of accented syllables within spoken utterances (see Ulbrich, 2005:164).

The analysis of the f0-contour of all accented syllables in the read news messages and the fairytale showed that Swiss German speakers realized more rising than falling f0-movements on accented syllables. The following table details the percentages of rising and falling f0-contours in read news messages and the fairytale produced by 10 German and 10 Swiss German speakers.

standard variety	rising f0		falling f0	
	news	fairytale	news	fairytale
German	50%	52%	50%	48%
Swiss German	28%	36%	62%	64%

Table 1: Percentage of rising and falling f0-patterns in German and Swiss German read speech

The first part of the present study aims to investigate a possible relationship between the realisation of rising pitch pattern and the lengthening in accented syllables in German and Swiss German read speech.

3. Methods

A large variability on the prosodic and the segmental level of spoken language does not always allow for a clear demarcation of regional, national, social, stylistic, situational variants. Therefore, the present study is based on model speakers (Ammon, 1995). To guarantee for direct inter-speaker comparability only read speech was analysed in the present study.

3.1. Subjects and recordings

In the German speaking countries news readers in national public broadcasting agencies have a comparable status. Their pronunciation experiences a comparable level of acceptance within their respective country and does not feature regional or dialectal characteristics. Acceptance and classification tests have shown that the speakers recorded for the present study fulfil these criteria (Ulbrich, 2005; Stock & Hollmach, 1996).

The data used in the present study are taken from a larger corpus investigating prosodic variation in German spoken in Germany, Austria and Switzerland. The corpus contains 435 min of read, semi-spontaneous and spontaneous speech produced by 30 Swiss, Austrian and German news readers. For the present study only read speech was analysed to allow for direct comparability amongst 10 Swiss German and 10 German speakers. The recordings were carried out in the sound proof studios of the public broadcasting agencies (ARD and ZDF in Germany and DRS II and SF DRS in Switzerland). For each speaker approximately 10 min of read speech were analysed from the recordings of 11 news messages and the fairytale.

3.2. Data preparation and analysis

The data were prosodically annotated by four trained phoneticians using an adaptation of the IViE system (Grabe, Nolan & Farrar, 1998). The prosodic transcription additionally involved a judgement of prosodic cues being used in the accent realisation including an evaluation of lengthening, pitch movement and increased loudness. The acoustic measurements included measurements of duration and f0 in accented and post-accented syllables. The read news and the fairytale are highly standardized text types so that it was not surprising that in the majority all speakers placed the pitch accents on the same syllables. To a small extent, however, inter-speaker variation occurred. For the analysis only those syllables were selected which were annotated as accented in the realisations by all 20 speakers.

Excluded from the analysis were sentence and IP (Intonational Phrase) final pitch accents. Both, phrase final lengthening and a final fall in f0 were shown – e.g. by Klatt (1975) and Lehiste (1973) already – to serve as prosodic cues in the realisation of boundaries of syntactic and/or prosodic units.

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The following annotations and measurements were analysed initially within the present study:

- Perceivable lengthening
- Duration of accented syllable (ms)
- Annotation of pitch accent pattern

Table 2 provides information about the number of syllables analysed in the present study.

	rising pitch patterns		falling pitch patterns	
	news	fairytale	news	fairytale
in total (20 Speakers	1540	1240	1740	1620

Table 2: Number of rising and falling pitch patterns in news messages and in the fairytale

4. Results

In the first section the results of the auditory cross-varietal comparison between German and Swiss German speakers are reported. The second section deals with the results of the acoustic analysis. A correlation analysis using the variables duration and relative number of rising pitch realisations was carried out to account for cross-varietal differences. The third section demonstrates findings on the variation in the phonetic realisation of rising pitch accents and their dependency on voicing and vowel length in Swiss German and German.

4.1. Auditory results of the cross-varietal comparison

The analysis of the prosodic annotation of accented syllables in read utterances showed cross-varietal differences between Swiss German and German speakers in the cueing of accented syllables. In the Swiss German data 90% of the accented syllables in the news messages and 86% of the accented syllables in the fairytale were annotated as lengthened. In the German realisation only 42% in the news messages and 56% in the fairytale were annotated as lengthened. However, pitch movement was perceived as primary cue for accentuation in both varieties. In the Swiss German utterances lengthening was annotated as the secondary cue. In German utterance approximately half of the accented syllables were annotated to be lengthened. Increased loudness, however, appeared to be a more salient perceptual cue and was annotated in 67% (news) and 75% (fairytale) of accented syllables.

4.2. Results of the interaction between pitch patterns and lengthening in cross-varietal data

Since the corpus is based on segmental-phonetically identical speech data, absolute duration measurements allow for a direct inter-speaker comparison. Additionally, using relatively standardized discourse types, the influence of para-linguistic and extra-linguistic aspects of speech can be neglected.
The ***duration*** measurements – taken in the nucleus – showed that Swiss German speaker produced vowels in accented syllables significantly longer compared to the German speakers ($F_{(1,18)} = 19{,}25$, $p < .05$).

	German	Swiss German
long vowels	135 ms	168 ms
short vowels	98 ms	137 ms

Table 3: average vowel duration in long and short vowels produced by German and Swiss German speakers

These acoustic findings confirm the results of the auditory annotation of lengthening (see 4.1. above).
Previous findings of a cross-varietal comparison of ***pitch realisations*** in Swiss German and German utterances showed differences in number and phonetic realisation of rising and falling pitch patterns (see table 1). An initial analysis was carried out to examine the question if those observed cross-varietal differences can be explained by the duration of the accented syllable or the duration of the vowel within the accented syllable insofar that the more frequent realisation of rising pitch patterns by Swiss German speakers is positively correlated to a comparably longer duration of accented syllables. The hypothesis was given rise by the fact that rising pitch movement takes longer than falling pitch movement (Sundberg, 1979). That would imply that maybe rather than being phonological in nature differences in the number of rising pitch patterns between the two standard varieties can be explained by means of articulatory effort and therefore biomechanical mechanisms (Xu, 2000). A mean syllable and vowel duration was calculated from the averaged syllable and vowel duration of each syllable found to be accented by all 20 speakers. For the analysis the average syllable and vowel duration produced by Swiss German speakers was subtracted from the average duration produced by German speakers providing a measure for lengthening. This appeared to be justifiable by the fact that the articulation rate was not found to differ significantly between speakers of the two German standard varieties. The second variable was the number of Swiss German speakers producing rising pitch patterns as opposed to a falling pattern produced by the majority (>7) German speakers. The analysis showed no correlation between a preference of rising pitch accent patterns in Swiss German realisations compared to the German data, depending on syllable or vowel duration. These findings led to the conclusion that cross-varietal differences in the number of rising and falling pitch patterns between the two German standard varieties could not be explained by the interaction of syllable/vowel duration and choice of pitch pattern.
A second analysis involved an ANOVA comparing syllable and vowel duration in rising and falling pitch patterns within the two groups of speakers. This analysis aimed to seek evidence that generally longer duration is associated with rising pitch movement, shorter duration with falling pitch movement. Again, no such dependencies were found. The findings suggest that the choice of the pitch accent pattern is independent of lengthening or duration of accented syllables.

4.3. Results of the cross-varietal analysis in the realisation of rising pitch accent patterns

The following section deals with the variation in the phonetic realisation of rising pitch accents. F0-excursion in pitch patterns usually involves the accented syllable and at least the post-accented syllable. For Swiss German realisations of pitch accents, it was shown that the unaccented syllable preceding

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the accented syllable is crucially involved in the realisation of pitch accents (Ulbrich, 2006, for leading tones see Grice, 1995). Relevant to the present study, however, are systematic differences between speakers of the two German standard varieties in the realisation of rising pitch patterns. Swiss German speakers were found to produce a significantly larger f0-interval in rising pitch accents often perceptually described as an upwards glide (Ulbrich, 2005). The following analysis was carried out to examine the relationship between segmental duration and f0-excurison. Additionally, the continuity in voicing within the segmental material of the accent patterns (including accented and post-accented syllable) was considered in the analysis. It was distinguished between discontinuously and continuously voiced segmental material:

discontinuous: <einfachsten> (easiest) [**aɪnfaxstən**]
continuous: <einfühlsam> (sensitive) [**aɪnfylzam**]

Furthermore, a distinction was made between accented syllables with a long vowel (or diphthong) or a short vowel. The following measurements were taken (Fig. 1):

i) the duration of the segmental material covered by the complete f0-excursion of the rising pitch accent pattern (t_{accent})
ii) the duration of the f0-rise covered in the accented syllable ($t_{A\text{-}syll}$)
iii) $t_{A\text{-}syll}$ expressed as relative portion of t_{accent} ($t_{\%}$)
iv) f0-rise covered in the entire pitch accent pattern ($f0_{accent}$)
v) the f0-excursion on the accented syllable ($f0_{A\text{-}syll}$)
vi) f0-rise covered in the post-accented syllable ($f0_{post\_A}$)
vii) $f0_{A\text{-}syll}$ expressed as relative portion of $f0_{accent}$ ($f0_{\%}$)

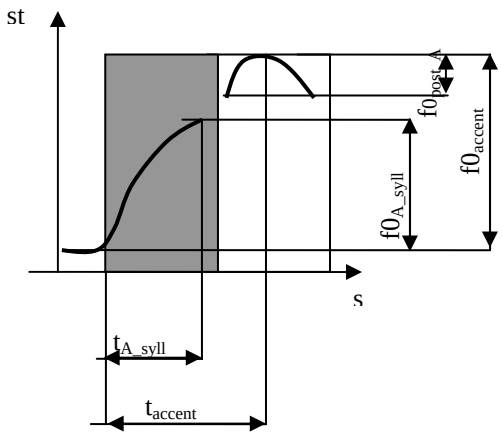

Figure 1: f0-excursion and duration in accent pattern, accented syllable (shaded) and post-accented syllable (white)

The measurements were used to examine:
i) significant differences between $f0_{accent}$ produced by Swiss German and German speakers
ii) significant differences between $f0_{A\text{-}syll}$ produced by Swiss German and German speakers
iii) influence of segmental duration on f0-excursion
iv) influence of voicing on f0-excursion

The results of an ANOVA showed significant differences between the speakers of the two German standard varieties in both, discontinuously and continuously voiced segmental material. $f0_{accent}$ ($F_{(1,18)} = 9{,}32$; $p < .05$) and $f0_{A\_syll}$. ($F_{(1,18)} = 12{,}65$; $p < .05$) were significantly larger in Swiss German than in German realisations. The f0-excursion covered within the post-accented syllable showed no significant differences between speakers of the two German standard varieties. An illustration of the findings is given in Figure 2. Results are summarized in table 3.

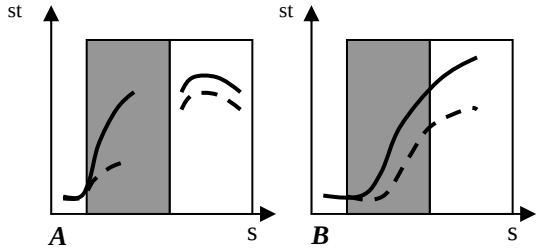

Figure 2: prototypical rising pitch patterns in German (dotted line) and Swiss German in discontinuously *(A)* and continuously *(B)* voice accented (shaded) and post-accented syllables (white)

	German	Swiss German
Discont_ $f0_{accent}$	142 Hz	155 Hz
Discont_ $f0_{A\_syll}$	98 Hz	133 Hz
Cont_ $f0_{accent}$	128 Hz	152 Hz
Cont_ $f0_{A\_syll}$	106 Hz	137 Hz

Table 3: $f0_{accent}$ and $f0_{A\_syll}$ in continuously and discontinuously voiced rising pitch accents

Although, the statistical analysis showed no interaction with the voicing of the segmental material systematic differences were found between the two groups. $f0_{accent}$ produced by German speakers appeared to be larger in discontinuously voiced material than in continuously voiced material whereas in Swiss German realisations no such difference was found.
A more detailed organisation of the speech data regarding the phonological syllable structure was established to aid the analysis of a combinatory influence of continuity in voicing and vowel length and how this might affect $f0_{accent}$ and $f0_{A\_syll}$ differently in the two groups of speakers. A subset of syllables was selected commencing with a voiceless consonant (C_{VL}). The nucleus contained either long vowels and diphthongs (V:) or short vowels (V). The syllable coda was either voiceless (C_{VL}) or voiced (C_V).

This results in the following combinations:
<$C_{VL}V{:}C_V$> (N=6 per speaker, total 120)
<$C_{VL}V{:}C_{VL}$> (N=6 per speaker, total 120)
<$C_{VL}VC_V$> (N=6 per speaker, total 120)
<$C_{VL}VC_{VL}$> (N=6 per speaker, total 120)

The post-accented syllable was entirely voiced. In the two groups of speakers $f0_{A\_syll}$ was compared for the four subsets of accented syllables within the two groups of speakers and the following ranking was found in both, the German and the Swiss German variety. The largest f0-excursion ($f0_{A\_syll}$) was produced in accented syllables containing a long vowel regardless the voicing of the coda. That suggests that the largest portion of the f0-excursion is executed in the vowel.

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Syllable structure	German	Swiss German
$C_{VL}V{:}C_V$	121 Hz	152 Hz
$C_{VL}V{:}C_{VL}$	117 Hz	147 Hz
$C_{VL}VC_V$	98 Hz	124 Hz
$C_{VL}VC_{VL}$	86 Hz	118 Hz

Table 4: f0-excursion in accented syllables

A different picture emerged when $f0_{accent}$ was considered. The speakers of the two varieties differed in their ranking (Table 5).

Syllable structure	German	Swiss German
$C_{VL}V{:}C_V$	126 Hz	155 Hz
$C_{VL}V{:}C_{VL}$	147 Hz	152 Hz
$C_{VL}VC_V$	109 Hz	138 Hz
$C_{VL}VC_{VL}$	144 Hz	127 Hz

Table 5: f0-excursion in rising pitch accent patterns

These finding suggest that there are differences between speakers of the two German standard varieties with respect to the use of the segmental material in the production of f0-rises in rising pitch accents. Swiss German speakers appeared to complete the largest part of the f0-rise within the accented syllables whereas German speakers used the voiceless syllable coda of the accented syllable to produce a jump in f0 to reach a higher f0 in the post-accented syllable.
A comparison of the relative portion ($f0_{\%}$) of the f0-rise covered within the accented syllable was carried out. In the German data $f0_{\%}$ was found to be larger in continuously voiced segmental material than in discontinuously voiced segmental material. In the Swiss German data no such difference was found (Numbers), $f0_{\%}$ generally covered more than 80%. The findings are summarized in the following table.

Syllable structure	German	Swiss German
$C_{VL}V{:}C_V$	96%	98%
$C_{VL}V{:}C_{VL}$	79%	97%
$C_{VL}VC_V$	89%	84%
$C_{VL}VC_{VL}$	59%	93%

Table 6: f0-excursion in accented syllables (in %) in Swiss German and German rising pitch accents

These findings suggest a positive correlation between the duration and the f0-excursion of accented syllables in rising pitch patterns produced by Swiss German speakers but not in German realisations. The scatter plot in Figure 3 confirms those expectations. The data of the German speakers are illustrated with squares, the data of the Swiss German speakers with circles. The Swiss data show a positive correlation between the f0-excursion and the duration of the accented syllable.

		F0_G	T_G
F0_G	Pearson Correlation	1	.032
	Sig. (2-tailed)	.	.726
	N	120	120
T_G	Pearson Correlation	.032	1
	Sig. (2-tailed)	.726	.
	N	120	120

Table 7: results of the correlation analysis in German realisations of rising pitch patterns

		F0_SG	T_SG
F0_SG	Pearson Correlation	1	.785(**)
	Sig. (2-tailed)	.	.000
	N	120	120
T_SG	Pearson Correlation	.785(**)	1
	Sig. (2-tailed)	.000	.
	N	120	120

** *Correlation is significant at the 0.01 level (2-tailed).*
Table 8: results of the correlation analysis in Swiss German realisations of rising pitch patterns

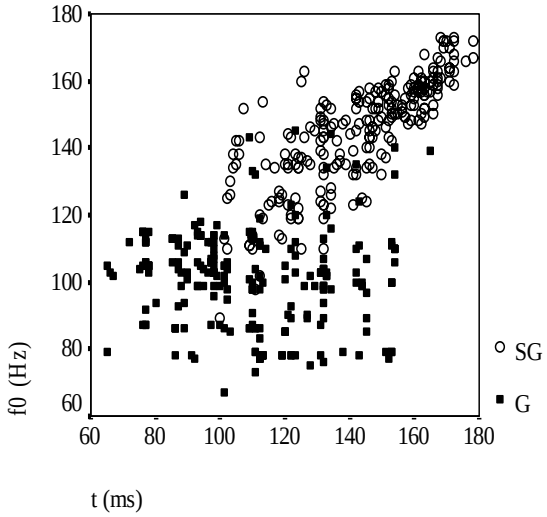

Figure 3: correlation of f0-excursion and duration in accented syllables of rising pitch patterns in German and Swiss German

It seems worth noticing that the scatter plots illustrate the cross-linguistic differences on the tonal and temporal level between speakers of the two German standard varieties. Swiss speakers produce accent patterns generally with a longer duration and a larger f0-excursion compared to the German speakers.

5. Summary

The present study was carried out to investigate interactions between timing and tonal aspects of speech using cross-varietal data. The analysis was based on recordings of read speech to allow for a direct inter-speaker comparability. One aim was to seek evidence that a preference of rising pitch accent patterns in Swiss German is due to longer duration of the accented syllables and/or vowels compared to German speakers who produced more falling pitch accents with a shorter syllable and/or vowel duration. The second aim was to investigate the influence of segmental duration and voicing in the accented and post-accented syllables on the phonetic realisation of f0-excursion in rising pitch patterns. The following results were obtained:

i) No positive correlation between longer duration and a preference for rising pitch patterns was found to account for cross-varietal differences
ii) No positive correlation between the duration and the choice of pitch patterns was found within the two groups of speakers

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iii) Swiss German and German speakers differed in the excursion of the f0-rise covered in accented syllables ($f0_{A\_syll}$) as well as in rising pitch patterns involving accented and post-accented syllables ($f0_{accent}$). The differences were found to be related to the voicing of the segmental material and its continuity.

iv) A positive correlation between f0-excursion and duration in accented syllables of rising pitch patterns was found in the Swiss German data but not in the German data

The present study provides preliminary results of dependencies between the prosodic and the segmental phonetic level and the interaction of prosodic features. The findings suggest that previously found differences between the two German standard varieties are due to the interaction between segmental timing and pitch movement. German and Swiss German speakers appear to employ different strategies in the execution of f0-excursion in rising pitch patterns. While Swiss German speakers show a strong relationship between vowel duration and f0-excursion in rising pitch accents German speakers use the pitch-'gap' provided by the voiceless syllable coda to enlarge the f0-excursion. Within the present study the consideration of e.g. peak alignment, variation in speech rate and communicative function was not possible. Therefore, follow-up research on the basis of a more carefully designed speech corpus to explore further influences of the segmental material on the prosodic level is needed. Subsequently, future findings might lead to the conclusion that cross-varietal or cross-linguistic differences in the realisation of pitch patterns may not necessarily point towards phonological differences in the intonational inventory but rather towards different strategies in the exploitation of segmental resource provided by a specific variety or language.

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