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Comparing Formants and Vowel Duration in Standard and Non-Standard Varieties of Nepali

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Abstract

This instrumental study of vowel production examines the effect of region and phonological context of three key acoustic parameters of vowel quality : F1, F2 and vowel duration. Data from 22 speakers of Nepali from four geographical regions was collected through field interviews using structured elicitation techniques. Linear mixed effects models with fixed and random effects were used for statistical modeling of the acoustic measures. Results indicate a significant of region on vowel duration.

Keywords: Nepali, Darjeeling, Dooars, Sikkim, F1, F2, vowel duration, mixed effects models.

1.Introduction

From studies of regional variation in American English, Dutch and Swedish, it emerges that acoustic parameters such as F1, F2 and vowel duration are affected by speakers' geographical location. These studies also show that descriptions of vowel inventories are further enriched with studies on the regional varieties of the language. Considering the fact that Nepali is spoken in pockets throughout the Himalayan belt in different linguistic and social settings, there was a need to supplement existing impressionistic accounts of Nepali vowel inventory with instrumental data. This production study was designed to fill the lacuna existing in terms of instrumental studies of regional vowel variation in Nepali. The research goal for this study is to examine two important acoustic parameters of vowel quality (F1 and F2) and vowel duration as a function of the geographical locale of Nepali speakers.

2.Background

The development of the sound spectrograph at the height of World War II had major implications for linguistic research especially in studies concerning speech production and perception. Spectrographic analysis presented a significant alternative to impressionistic transcription because of its empirical and objective character. Ever since the publication of the results of the Peterson and Barney (1952) study, instrumental techniques have been widely employed by phoneticians and sociolinguists in the study of segmental and prosodic phenomena. The sub-discipline of sociophonetics has emerged on the shoulders of instrumental techniques with a constantly growing body of literature on the interface of phonetics and sociolinguistics.

The much cited Peterson and Barney (1952) study, PB hereafter, used spectrographic analysis to demonstrate that vowel quality in American English could be described in terms of

their steady state frequencies. The PB study results became representative of the vowel system of General American English, a notion that was countered by subsequent studies (Hilllenbrand, Getty, Clark and Wheeler, 1995; Hagiwara, 1997; Clopper, Pisoni and De Jong, 2005). Hillenbrand et al. (1995) simulated the famous PB study taking additional acoustic measures with speakers from the northern Midwest region of the United States and found that [æ] was considerable raised and fronted for speakers in the northern Midwest region when compared to the PB study, which had used data for speakers from the mid-Atlantic region. They also noticed the differences in the production of [ɑ],which was fronted and central relative to its low-back postion in the PB study. This effect as a function of dialect was attributed to the Northern Cities Chain Shift described by Labov, Yaeger and Steiner(1972).

Hagiwara (1997) compared steady state vowel formant data from southern Californian speakers to the observations from the PB study and the study by Hillenbrand et al. (1995). Hagiwara found major differences between the PB study and the study by Hillenbrand et al. (1995) with reference to the positioning of the high back vowels [u] and [ʊ] which were relatively central on account of the absence of lip rounding, a feature typical of Californian speech, causing higher F2 values. Similar observation was made with regard to [ʌ] when data from southern California was compared with results from the PB study.

Clopper et al. (2005) investigated six regional variants of American English and found the ongoing region-specific vowel chain shifts and mergers influencing vowel quality. More evidence of regional vowel variation is seen in the varieties of standard Dutch spoken in Netherlands and the Flanders region in Belgium (Adank, van Hout and van de Velde, 2006).

Adank et al. (2006) find statistically significant differences for steady state formant frequencies, spectral change and vowel duration between and within the two regions. Therefore, there is now a growing body of evidence, which indicates that speakers' regional affiliation has a strong bearing on aspects of vowel quality and characterization of vowel systems in languages suggesting that its descriptions must be supplemented by accounts of its varieties.

The motivation for this paper stems from the lack of variation-based accounts of the Nepali vowel system considering the vast geographical stretch and variety of social settings where the Nepali speech community resides. Nepali is spoken in small pockets throughout the Himalayan region in South Asia. It is the national language of Nepal and inIndia it is spoken in a vast area stretching from the state of Jammu and Kashmir in the north all the way to Mizoram in the north-east. It is also spoken in small pockets in Myanmar and southern Bhutan.

Phonological descriptions of Nepali, however, have focused almost entirely on the eastern dialect of Nepali spoken in areas in and around the Kathmandu valley and eastern Nepal. Descriptive (Bandhu, Dahal, Holzhausen, & Hale, 1971; Acharya, 1991)as well as instrumental (Pokharel, 1989; Khatiwada, 2009) analyses of the Nepali speech segments are based on data from talkers speaking the standard variant.

A dialect-oriented survey and analysis has been conducted by the Language Division of the Office of the Registrar General of India as part of the Linguistic Survey of India, hereafter

referred to as the LSI. Preliminary drafts based on impressionistic transcriptions indicate variation in vowel inventories in Nepali as spoken in the states of West Bengal , hereafter WB (Srivastava, 2011) , Sikkim (Nakeerar, 2011) and Himachal Pradesh, hereafter HP (Baskaran,2011) where the survey was conducted.

3.Nepali vowel system

The vowel system of Nepaliis traditionally characterized by the presence of 11 contrastive phonemes. It has six oral (/i, e, ɑ, ʌ, o, u/)and five nasal(/ĩ,ẽ,ɑ̃,ʌ̃,ũ /) vowels. Though nasalized [õ] appears sporadically in words such as [õt̪ʰ] '*lips*', [hõt͡so] '*low*',[kʰõt͡s] '*remote or far-flung*', [kʰõɽe] '*irregular*'], it bears no phonological contrast with [o]. The central-mid vowel /ə/ has been subject to different interpretations with Bandhu et al.(1971) and Acharya (1991) describing it as a 'schwa' whereas instrumental accounts by Pokharel (1989), Khatiwada (2007) and Lohagun (2016) characterize it as a low-mid back rounded vowel represented by a 'wedge'/ʌ/. LSI reports them as /ə/ for the WB, Sikkim and the HPvarieties. Srivastava (2011) notes six oral vowels for WB Nepali but Nakeerar (2011) finds seven for the Sikkim, and 7 vowel phonemes were identified in the HP variety by Baskaran (2011). For Sikkim, apart from the six vowels found in traditional descriptions, the mention of the presence of /ɔ/could be another variant of /ə/ as pointed out by Khatiwada (2009, p.338). The LSI report for Nepali in HP, while documenting the regular six vowels including /ə/, also indicates the presence of /ɛ/. This could possibly be an artifact resulting from language contact with Hindi and other local languages spoken in the region. Most Nepali speakers are multilingual and speak the local language(s) of the region.

4.Method

4.1 Regions

The present study analyzes a subset of Nepali vowels (oral monophthongs) from speakers of the "standard" Nepali from Nepal, speakers from Sikkim and speakers from the Darjeeling and Alipurduar districts of West Bengal in India. Data for this study was collected through extensive fieldwork in Rahimabad Tea Estate and surrounding areas of the Alipurduar district of West Bengal; Gangtok in Sikkim; Kurseong in the Darjeeling district of West Bengal; and university students from Nepal studying in New Delhi who speak the Eastern dialect of Nepali which is considered to be the standard dialect.

The term 'Dooars' is synonymous to the Alipurduar region and the dialect of Nepali spoken there will be referred to as the Dooars variety. To a large extent, speakers in all the regions are multilingual. The Dooars region is a relatively deprived in socio-economic terms. Education levels are low and majority of the people in this region are tea-garden labourers. The linguistic landscape is relatively rich in comparison. Four major communities, each with its own native language, inhabit the region – the Bengalis, the Nepalis, the Biharis and the *adivasis* (tribals). The population, in general, is largely multilingual speaking Bangla, Nepali, Hindi and Sadri (most refer to it as Adivasi) in various domains. There was one single school in the region where the fieldwork was conducted, which used English as a medium of instruction and only till the fourth grade. Other schools instructed pupils either in Hindi or Bangla with no schools using Nepali for education. The Devanagari script being common to Hindi and Nepali orthography, the participants in the study were administered a wordlist and a reading passage for data elicitation.

Three females and two males in the age bracket of 25-37 were interviewed from areas neighbouring Rahimabad T.E. in Alipurduar district.

The Darjeeling district is the northernmost district of West Bengal. Four sub-divisions namely Darjeeling Sadar, Kalimpong, Kurseong and Siliguri constitute the district out of which the first three are located in the hilly regions while Siliguri sub-division falls in the Terai region at the foothills. The district shares two international boundaries with Nepal in the west and Bhutan in the east. The state of Sikkim lies in the north of the Darjeeling district. The southern side is bound by the Jalpaiguri district of West Bengal. The Nepali speaking population in the Darjeeling district has been living in the area for more than two centuries now and has since come in contact with languages like Hindi, Bangla, Tibetan, Lepcha, Santhali, Munda, Oraon, Rajbanshi and several other dialects. Nepali has, however, established itself as the lingua franca of the three sub-divisions, namely, Darjeeling Sadar, Kurseong and Kalimpong along with certain portions of the Terai region.

Sikkim is a state in northeast India where Nepali is widely spoken. There are other speech communities such as the Bhutia and the Lepcha but Nepali is widely used across the state in the spheres of education, formal and informal official communication, newspapers and periodicals, legislative deliberations and judicial functions. Multilingualism prevails in this region too with speakers resorting to Nepali, Hindi, English, Lepcha and Bhutia in different spheres of life. Three male and two female participants in the age group of 22 – 37 were interviewed.

Nepali is the official language in Nepal where 11,100,000 people (Census of Nepal 2001) speak the language. According to Acharya (1991), there are many social variants of Nepali. Within Nepal, there are three dialects – Western, Central and Eastern, depending upon geographical factors as well as social hierarchy. The eastern dialect is considered to be the source for the standardized dialect. However, even within these three broad categories, there are further variations. Acharya (1991 :6) notes the Darjeeling variety of Nepali to be another distinct variety.

4.2 Participants

A total of 22 speakers of Nepali – four males and two females from Darjeeling; four males and two females from Sikkim, three males and two females from Nepal; and two males and three females from Dooars - participated in the study. None of the participants had any noticeable speech deficits. The average age for speakers was 31, 38, 26 and 32 for Nepal, Darjeeling, Sikkim and Dooars, respectively. Basic literacy was an important factor in participant recruitment as a wordlist was administered for data elicitation. The participants were informed of the aims and objectives of the research and informed consent was taken from all the participants before recording the samples.

4.3 Stimulus and Recording

Data for this study was collected through field interviews in each of the four regions. In Rahimabad, help from a local member of the community was solicited to reach out to participants and to minimize the interviewer effect. Contrary to studies in experimental phonetics which relies on laboratory recordings, a facility as such was not available in all the regions.

Although recording was done in field settings - usually at the participant's residence, vacant classrooms and student housing rooms, every effort was made to mitigate background noise in order to ensure that the recordings could be used for acoustic analysis. Wordlist style data elicitation technique was adopted as it yields longer and stressed tokens, which are best suited for acoustic studies. The participants were asked to read out from a wordlist with the target vowels in four different phonetic contexts: preceding voiceless stop consonants [tVpi], preceding laterals [t͡sVli] and preceding rhotics [tVɾi]. Each word was repeated thrice. All interviews were recorded in the Waveform Audio File (.wav) format with 16-bit quantization and sampling frequency of 44.1 kHz using a Zoom H1 Handy Recorder. The recordings were made in field settings and every effort was made to mitigate background noise. Every word was repeated thrice by all the participants. This allowed the inclusion of more tokens for analysis.

4.4 Acoustic Measurements, Normalization and Statistical Testing

Sound files for every speaker was coded with name initials, age, sex and region and automatically segmented using the Penn Phonetics Lab Forced Alignment Tool (Yuan & Liberman, 2008)[1]. The alignments were hand-checked and manually corrected for errors. Onset of F2 after a burst was used for determination of onset whereas the point where vocal fold vibration started trailing off was taken as the cue for offset determination. A total of 1182 tokens were analyzed for three acoustic parameters F1, F2 and vowel duration. A script was used to extract vowel duration and formant measurements 50% through the course of the vowel in Praat (Boersma,2001) .

Normalization was deemed necessary in order to eliminate variation in measurements caused due to physiological differences in the vocal tracts of males and females. Figure1 below shows the differences in acoustic space areas computed on the basis of normalized values in the top row and unnormalized formant frequencies in the bottom row. It is evident from figure 1 that vowel space areas based on normalized values minimizes the physiological differences between males and females.

[1] For the purposes of this study, the P2FA was adapted for use on Nepali speech data. The P2FA is based on acoustic models of American English. A pronunciation dictionary for items in the wordlist was compiled using the ARPABET transliteration scheme adopted by CMU Pronunciation Dictionary used in the P2FA.The phone set of the CMU Pronunciation Dictionary contains the set of vowels for Nepali.

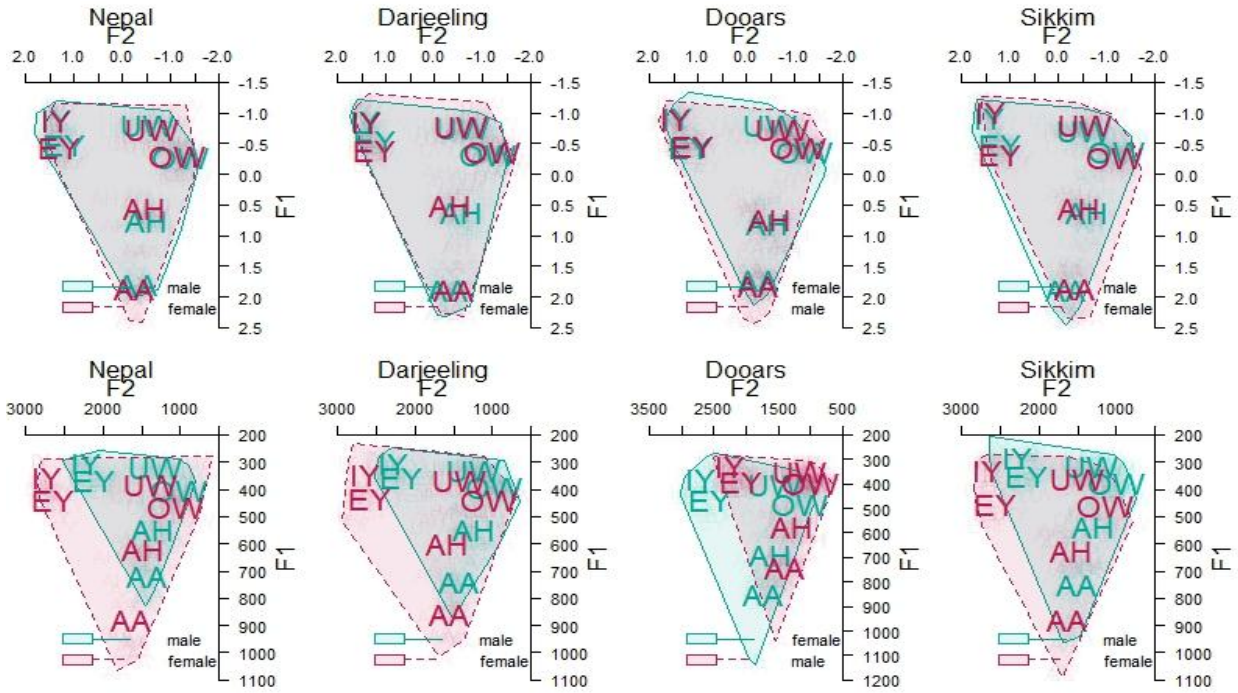

Figure 1

Another motivation behind carrying out normalization was to preserve dialectal differences in vowel quality (Thomas, 2011:161). For this study, formant measurements (F1 and F2) were normalized using the Lobanov normalization algorithm through NORM (Thomas & Kendall, 2007).The Lobanov formula ($z = (f - \square) \div \sigma$) (Lobanov, 1971) is a vowel-extrinsic and speaker intrinsic technique which calculates a *z-score* of each formant for a speaker by dividing the difference between the raw Hertz values of a formant (f) and its mean value (μ) for all the vowels by the standard deviation (σ) for that formant across vowels for that speaker. Though vowel extrinsic methods may not be suitable for comparing two or more languages with different vowel inventories (Disner, 1980), the Lobanov method in particular is known to perform better than vowel-intrinsic procedures in preserving social and regional information for a single language while eliminating variation due to physiological factors (Adank et al., 2004, Clopper, 2009, Flynn and Foulkes, 2011).

Linear mixed effects models with fixed and random effects were used for statistical analysis using the lme 4 package (Bates et al. 2015) in R (R Core Team, 2013). In order to resolves non-independencies of data because of repetitions of the same token for a vowel category by every speaker it was essential that a mixed effect approach was adopted which accounts for the variability arising out of both the fixed and random effects. Therefore, region, phonetic environment and repetition were kept as fixed effects while speaker was retained in the model as a random effect. For each acoustic measure (F1, F2 and vowel duration), three models were built: a full model with all the fixed and random effects; and two reduced models without one of the fixed effects. The full model and the reduced models were then compared using a maximum likelihood ratio test to gauge the significance of the fixed effects on the model.

5. Results

Table 1 presents the significance of the fixed effects on the acoustic measures based on a one way ANOVA of the full and the reduced models. Results based on maximum likelihood ratio test revealed significant effect of region on the vowel duration across all categories but a significant effect of region on F1 for the vowel /ɑ/ and F2 for [ʌ]. Phonetic context as a fixed effect had a significant effect on all the acoustic measures under investigation across vowel categories.

Table 1

	Region			Phonetic Context		
Vowel category	F1	F2	Duration	F1	F2	Duration
[i]	-	-	**	-	**	***
[e]	-	-	**	**	-	***
[ɑ]	*	-	*	**	***	***
[ʌ]	-	**	***	*	***	***
[o]	-	-	*	-	***	***
[u]	-	-	**	**	***	***
"-" = not significant, "*"= p<0.05, "**" = p<0.01, "***" = p<0.001						

5.1 Durational Analysis

The duration of the vowel [i] in the Nepal dialect was found to be significantly longer than in the other three remaining dialects (for Darjeeling, t=-3.754 and p <0.01; for Sikkim, t= 3.645, p<0.01; for Dooars, t= -2.282, p<0.05). The vowel [i] preceding rhotics tends to be significantly shorter than in contexts where it occurs before voiceless oral stop consonants (t= -10.971, p<0.001). There is also a significant contrast between the duration of [i] before laterals and before rhotics (for preceding [ɾ], t = 9.487, p<0.001).

With respect to duration for the vowel [e], Nepal speakers contrasted significantly with speakers from Darjeeling (Darjeeling, t = -3.388 , p < 0.01) and Sikkim (Sikkim, -2.888, p < 0.01). There was a significant contrast between Darjeeling and Dooars speakers as well (Dooars, t = 2.586, p <0.05). No significant contrasts were observed between the Nepal and the Dooars dialects. Significant contrasts were also observed on the duration of [e] in between different phonetic contexts. The vowel [e] in token preceding liquids were longer in tokens preceding voiceless stop consonants (preceding [l], t = 5.289, p<0.001; preceding [ɾ], t = 15.806, p<0.001). There is also a contrast between tokens preceding [l] and [ɾ] (preceding [ɾ] t = 10.517, p<0.001).

For the duration of vowel /ɑ/, Nepal contrasts with Darjeeling and Sikkim speakers only (Darjeeling, t= -3.376, p <0.01; Sikkim, t= -3.110, p < 0.01) with negative t-values suggesting shorter durations with reference to Nepal speakers. Darjeeling, Sikkim and Dooars speakers do not contrast significantly. There is also a significant contrast between tokens in the three different phonetic contexts. Vowel tokens preceding liquids are longer than in contexts preceding voiceless oral stop consonants (preceding [l], t = 8.261, p < 0.001; preceding [ɾ], t= 14.344, p < 0.001). As in the case of the [e], there is a significant contrast between tokens preceding [l] and [ɾ] (preceding [ɾ]= t= 6.083, p<0.001.)

For the vowel /ʌ/, Nepal speakers again produce significantly longer tokens than the other three variants (Darjeeling, t = -5.655, p < 0.001; Dooars, t = -4.421, p<0.001, Sikkim, t = -5.425, p<0.001). Tokens preceding liquids are significantly longers in comparison to tokens preceding voiceless oral stops (preceding [l], t = 9.153, p < 0.001; preceding [ɾ], t= 17.161, p < 0.001). Significant contrast is also noted between tokens preceding [l] and [ɾ] (preceding [ɾ]= 8.008, p< 0.001.)

Nepal speakers contrasted with Darjeeling and Sikkim speakers with regard to the duration of vowel [o] (Darjeeling, t= -2.719, p <0.05; Sikkim, t = -2.426, p<0.05). Nepal speakers consistently produced longer tokens. Dooars speakers had significant contrast with speakers from Darjeeling (t= -2.479, p < 0.05) and Sikkim (t = 2.186, p < 0.05). Tokens before liquids were consistently longer than before preceding voiceless oral stops (preceding [l], t = -4.901, p<0.001; preceding [ɾ], t= -13.144, p<0.001). Compared to preceding laterals, tokens preceding rhotics were found to be longer (t = 8.243, p < 0.001).

For the vowel [u], as across all other vowel categories, Nepal speakers differ in terms of duration with speakers from Darjeeling (Nepal, t = 3.789, p < 0.01) and Sikkim (Nepal, t = -3.334, p < 0.01). Duration of [o] before rhotics was significantly longer in relation to tokens preceding voiceless stop consonants (t = 9.296, p < 0.001); tokens preceding laterals were noted to be significantly longer than before rhotics (t= 4.130, p < 0.001).

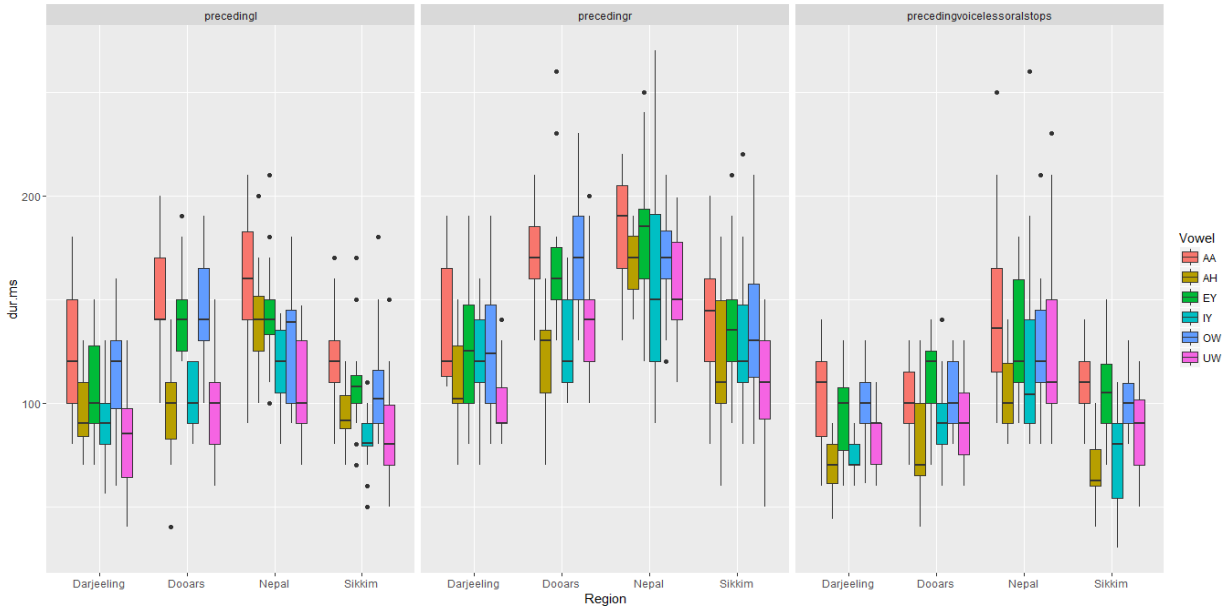

Figure 2

5.2 Formant Analysis

Fixed effect coefficients for the vowel [i] indicate a significant difference between Nepal and Dooars dialects with reference to F1 (Dooars, t=-2.384,p<0.05). There are no other significant contrasts between any other dialects. Nepal and Dooars speakers also contrast

significantly on F2 values (Dooars, t=2.342, p<0.05). For F2, in addition to significant contrasts with Nepal, the Dooars variety also contrasts significantly with speakers from Sikkim. (Dooars, t=2.113, p<0.05). On F1, there is a significant contrast between preceding voiceless oral stops and preceding laterals (preceding [l],t=2.277, p<0.05). Similarly for F2, there is a significant contrast between them (preceding [l], t=-3.284, p<0.01).

For F1 values of the vowel [e], there are no significant contrasts between any of the groups. However, for F2, there is a significant contrast between Nepal and Darjeeling (Darjeeling, t=2.164, p<0.05). In terms of F1, there is a significant contrast between tokens preceding laterals and rhotics (preceding [ɾ], t= -3.445, p<0.001). For F2, there is a contrast between preceding voiceless stop consonants and preceding laterals (preceding [l], t=-2.084, p<0.05).

F1 values for [ɑ], Nepal speakers do not contrast with speakers from any other dialect areas. However, along this dimension, Dooars speakers differ significantly with speakers from Darjeeling (Dooars, t= -3.738, p<0.01) and Sikkim (Dooars, t= -2.394, p<0.05). For F2 values of [ɑ], there is significant contrast between Nepal and Dooars speakers (Dooars, t= 2.152, p<0.05). No other significant contrast was observed for this acoustic measure for [ɑ] between dialect groups. Between phonetic environments there was a significant contrast between preceding voiceless stop consonants and laterals for F1 and F2 (F1 for preceding [l], t=-3.228, p <0.01; F2for preceding [l], t= 8.396, p <0.001). For F2, there is also a significant contrast between preceding voiceless stop consonants and preceding [ɾ] (preceding [ɾ], t=5.402, p<0.001). Significant contrasts exist in F1 and F2 values for tokens preceding [l] and preceding [ɾ] (F1 preceding [ɾ], t= 2.888, p <0.01; F2 preceding [ɾ], t= -2.993, p <0.01).Figure 3 presents a plot of means values of F1 and F2 differentiated by phonetic context.

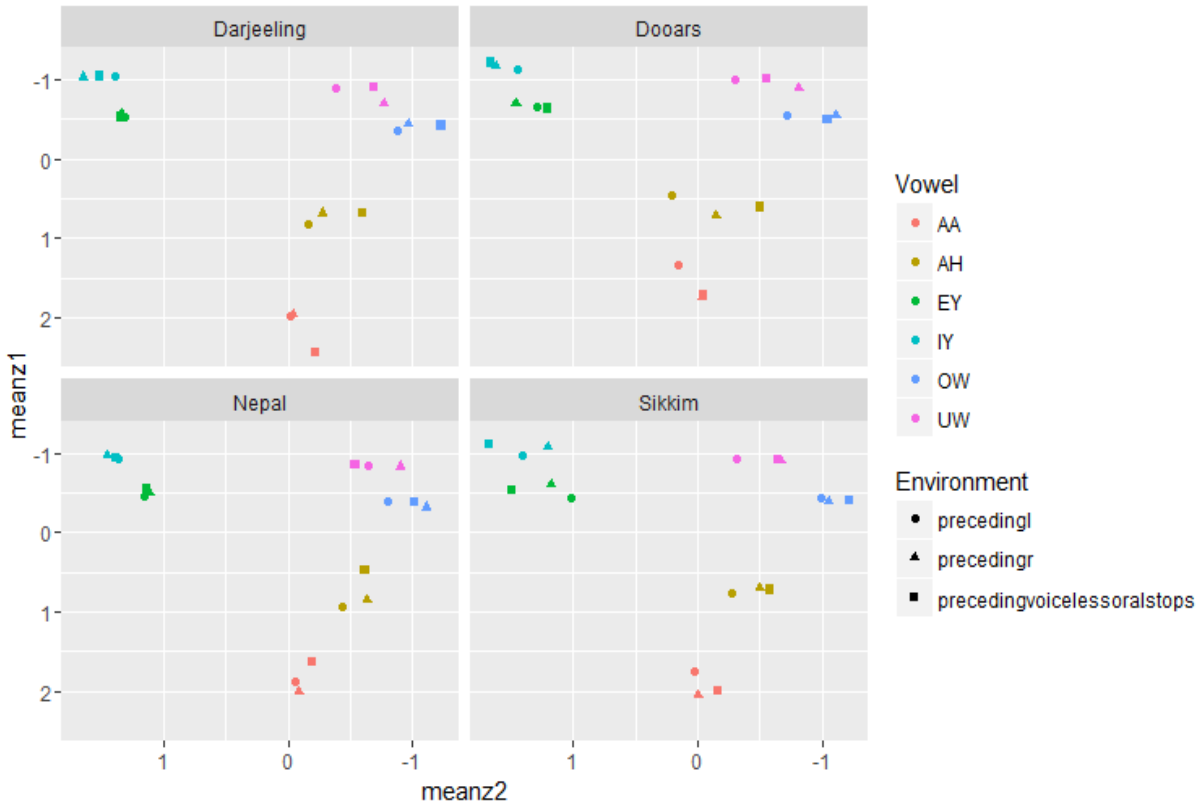

Figure 3

For the vowel [ʌ], there are no significant contrasts across dialect groups for F1. However for F2, Dooars speakers differ significantly from all other groups (Nepal, t = -4.426, p < 0.001; Darjeeling, t = -2.300, p < 0.05; Sikkim= t = 3.398, p < 0.01). For F2, there is a significant contrast betweenNepal and Darjeeling (Darjeeling, t = 2.333, p < 0.05). F1 and F2 values contrast significantly between token preceding voiceless oral stops and and tokens preceding liquids (F1 preceding [l], t = 2.285, p<0.05; F1preceding [ɾ], t= 2.079, p <0.05; F2 preceding [l], t= 10.373, p<0.001; F2preceding [ɾ], t= 4.734, p<0.001).For F2, there is a significant contrast between preceding [l] and preceding [ɾ] contexts (preceding [ɾ], t = -5.639, p < 0.001).

For the vowel [o], no significant differences between-dialect group contrast were observed for either F1 or F2 with the exception of Dooars and Sikkim speakers who contrasted significantly for F2 values (Sikkim , t = -2.284, p < 0.05). For F2, significant contrasts were observed between tokens preceding voiceless oral stops and preceding liquids (preceding [l], t = 6.902, p < 0.001; preceding [ɾ], t= 1.982, p< 0.05). For F2, significant contrast were also observed between preceding [l] and preceding [ɾ] (preceding [ɾ], t = -4.920, p<0.001).

For the vowel [u], Nepal speakers contrasted significantly with speakers from Dooars for F1 values (Dooars, t = -2.219, p<0.05). Darjeeling speakers also contrasted with speakers from Dooars for F1 (Dooars, t = -2.498, p< 0.05). For F2, there were no significant differences across groups. For F1, there is significant contrast between tokens preceding voiceless oral stops and preceding [ɾ] (preceding [ɾ], t = 2.809, p < 0.01). For F2, significant contrasts between tokens preceding voiceless oral stops and preceding [ɾ] (preceding [ɾ], t=-2.976, p<0.01), preceding

voiceless oral stops and preceding [l] (preceding [l],t= 3.557, p <0.001); and preceding [l] and preceding [ɾ](preceding [ɾ], t= -6.534, p<0.001).

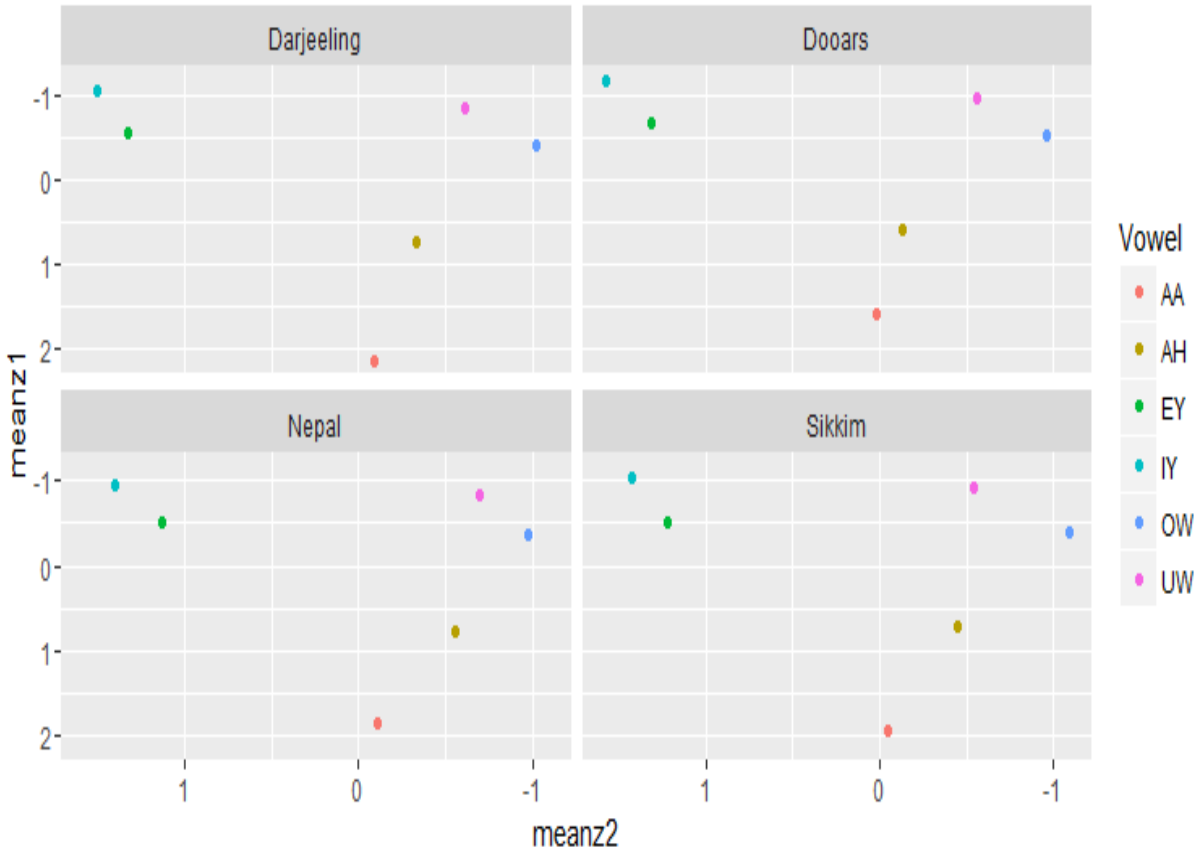

Figure 4

6. Conclusion

The objective of this paper was to examine the effect of region on F1, F2 and vowel duration of six oral monophthongs in four regional varieties of Nepali. The goal was to account for cross-dialectal differences and provide an instrumental account of the variation in vowel systems. Statistical analysis indicates that speakers' regional affiliation has a significant effect on vowel duration. Vowel duration across all categories in the standard variety spoken by speakers from Nepal tend to be longer than the other three variants. The variation in vowel duration as an effect of phonetic environment suggest language internal influence as tokens preceding liquids which are voiced segments were consistently longer than tokens preceding voiceless segments suggesting the effect of voicing on vowel duration.

With reference to the steady state frequencies, the linear mixed effects model only indicates significant effect of region on the height of the vowel [ɑ] and front-back dimension of the vowel [ʌ]. However, fixed effects coefficients for different vowels indicate contrasts between different groups. For the vowel [i], Nepal speakers contrasted only with Dooars speakers. The Dooars variant [i] is raised and fronted in comparison to the standard dialect. The Dooars speakers also produce a more fronted variant of [i] than Sikkim speakers. For the vowel [e],

Darjeeling speakers produce a more fronted variant than speakers of the standard dialect. With reference to the standard dialect speakers from Dooars produce a fronted variant of [ɑ]. The Dooars speakers also produce raised variant of [ɑ] when compared to speakers from Nepal and Sikkim. The vowel [ʌ] differs among groups mainly along the F2 axis. The Dooars and the Darjeeling variants of [ʌ] are fronted in comparison to the standard dialect. The vowel [o] in the Sikkim variant is further back in the vowel acoustic space than in any of the other varieties. Dooars speakers contrast with the speakers from Nepal and Darjeeling with regard to height of the vowel [u]. The Dooars variant of [u] is raised and therefore, is positioned higher in the vowel space.

In conclusion, the study reveals that both internal and external factors affect vowel variation in Nepali. Results tentatively show that speakers' regional affiliation has a significant effect on vowel duration. These results need to be further examined with a larger corpus of data involving more participants. Additionally the findings of this study can be supplemented by analysis of data from other elicitation styles such as reading passages and conversational data. The vowel space area can also be quantified through metrics such as the convex hull area or the formant space area for an analysis of dialectal differences is vowel space area.

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