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Effects of Forensically Relevant Face Coverings on Acoustic Properties of Pahari Central Vowels

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Abstract

This study investigates the face coverings' effects on the acoustic properties of two Pahari central vowels (ə, a:). Three types of face coverings (helmet, mask, niqab) are used in this study. Ten participants (five males and five females) are being selected to investigate this phenomenon. Speech material consists of two monosyllabic words (məl, ma:l) in CVC context and these words are repeated three times by each speaker. Praat software is used for recordings and getting formant (F1, F2) frequencies and duration. Regression analysis is performed to find out the face coverings' effects on acoustic properties of vowels. The results show that helmet, mask and niqab have significant effect on F1and F2 of /ə/ but has no significant affect on duration. In case of /a:/, the statistics show that mask and niqab donot have significant effect on F1, F2 and duration, but helmet has significant effect on F2 and duration.

Keywords: *Facewears, Central Vowels, Acoustic Analysis, Formants, Duration.*

Introduction

It is generally predicted that any material obstructing sound propagation will affect speech production and perception. According to Thomas (2002), even the angle of the speaker in relation to the listener may affect the sound quality. Masks and other types of face coverings are used to conceal the identity in crimes. The obstructing material can change the voice quality. Forensic face covering research area is relatively new. Llamas et al (2008) and Fetcher (2014) are the pioneers in this area. They examined how different types of face coverings affect the acoustic signals and how the listeners perceive the signals. Different studies have been conducted to investigate the effects of face coverings on consonants i.e. Saigusa, 2017. This study is an attempt to determine how different face coverings affect the acoustic properties of vowels. For this purpose two central vowels (ə, a) of Pahari language are selected for analysis. Pahari is a language which belongs to Indo-Aryan languages' family and they are sub-branches of Indo-European languages (Karnai, 2007). According to Khan (2013), there are 30 consonants and 12 monothongs in Pahari. Monothongs include: 1) six front vowels /i:/, /ɪ/, /e:/ , /e/, /æ:/ , /æ/; two central vowels /ə, a:/ and four back vowels /ʊ/,

/u:/. /o/, /o:/. Two acoustic parameters namely formant (F1 and F2) frequencies and duration have been selected for analysis. The present study uses three types of facial concealments: mask, niqab and helmet.

Research Objective

- To determine the effects of forensically relevant face coverings (helmet, mask, niqab) on acoustic properties (F1, F2 and Duration) of Pahari central vowels.

Research Question

- How forensically relevant face coverings affect the acoustic properties of Pahari central vowels?

Literature Review

According to Fecher (2014), the term 'facewear' is used to refer to variety of face and head wears which are used more or less commonly by people in daily life. There are various types of face wears used by people for religious, cultural, recreational and occupational purposes. Face coverings have an effect on the way the speech is produced.

Martinez and Lerten (2016) stated that criminals disguise themselves by wearing different types of facial concealment. This is a world in which video and photo surveillance is very common. Different types of facial concealments were used in film to illustrate popular culture like *V for Vendetta*. Similarly, different types of CCTV footages are shown in news where criminals disguise themselves by wearing masks or other concealments. The evidence collected against such individuals is from ear witnesses. Forensic phoneticians are asked to identify any speaker or any word in a recording that is of bad quality (Fraser, 2014).

Llamas et al. (2008) and Fecher (2014) studied effects of various kind of face covering on consonants acoustic speech signals and listeners' perception and speech intelligibility. Llamas et al. (2008) first experiment was conducted to check listener's perception of sounds which are produced by face wearings such as surgical mask, balaclava, and niqab (full-face veil), and also produced without any coverings (control). Place distinction confusion in fricatives was the most common error in this experiment. The loss of acoustic transmission was investigated by the sounds produced by wearing different types of material through loud speaker. These face wears included in this study are niqab (which is made of polyester), stockings (made of nylon), balaclava (made of acrylic yarn), handkerchief (made of cotton), surgical mask (made of paper), scarf (made of wool/acrylic blend), and a woven fabric used to cover loudspeaker (acoustically transparent).

Fecher (2014) also studied the voiceless stops and fricatives acoustically and these sounds were produced by wearing face coverings like a motorcycle helmet, a surgical mask, a strip of tape across the mouth, a niqab, balaclavas with and without mouth holes, a scarf , and a full-head rubber mask. The spectral peak, kurtosis, centre of gravity, skewness, intensity and standard deviation were measured to check the effects of face coverings on voice less fricatives. The significant effects of facewears were found on intensity and spectral moments of consonant sounds.

Assadi et.al (2015) investigated the effects of coverings on voiceless fricatives /f, s, ʃ/ in Farsi. The results showed that face wears have significant effects on intensity and spectral features of /f, s, ʃ/ sounds. The significant effects were found in intensity measures and least variation is found in case of spectral peaks. Saigusa (2017) also studied the effects of three different types of face wears (motorcycle helmet, balaclava, and plastic mask) on the acoustics of three English non-sibilant fricatives /f/, /θ/, and /v/. Two participants were included in this study. Significant effects of face wears were found on intensity, centre of gravity, standard deviation, skewness, and kurtosis.

From the above discussion indicate that lot of research has been done on the effects of face covering concealments on the acoustic properties of consonants, but no work has been conducted to show the effects of face covering concealments on vowels. The presents study aims to explore the effects of forensically relevant face covering concealments on the acoustic properties of Pahari central vowels /ə/ and /a:/.

Method

Participants

Five male and five female speakers between the ages of 20 to 35 participated in this study. The participants were the students of intermediate. They all were born and grown up in Pahari speaking area. All the participants are multilingual. They did not have any speech impairment. All of them had received no phonetic training or knowledge of this type of experiment.

Stimuli

The speech material consists of 2 monosyllabic words /məl/and /ma:l/ in CVC context. Each word was repeated three times. To minimize the effect of neighboring consonants, same consonants /m/ and /l/ are used in preceding (C1) and following (C2) the target Vowel. The total data set comprises of 240 tokens (10 speakers × 2 words × 3repetitions × 4 (1without face wear+3 facewear conditions).

Data Collection Procedure

The recordings were done in different locations in district Bagh, AJK. The participants seated comfortably wearing face covering in front of the laptop screen, wearing a headset microphone. The microphone was about two inches away from the left side of the participant's lips. There words with target vowels were displayed on laptop screen. The participants were asked to read each word three times. The participants were also instructed to read the words with normal speed. The ten participants gave a total of 240 tokens (10 speakers x 2 words x 3 repetitions x 4 face coverings). They were recorded directly on Praat software (www.praat.org) by using high fidelity microphone.

Measurements

Waveforms and spectrograms, for each target vowel, were used to determine the first two formants (F1 and F2) frequencies. The words were segmented on the basis of visual information on a wide band spectrum. F1 and F2 were determined and measured in Hz in the middle of the formants. Statistical analysis of the sounds was performed by IBM SPSS. To investigate the facewears' effects on the acoustic properties of vowels, F1, F2 and Duration, regression analysis was done. This type of analysis includes one independent and one dependent variable at one time. In this study mask, niqab and helmet are independent variables and without face covering (WFW) is dependent variable. Therefore, three regression models are run by changing the independent variable in each model

Results

a) Analysis of F1 of Sound /ə/ Helmet

Table 1. Regression Coefficient Model 1 of F1 of Sound /ə/ wearing Helmet

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	Beta	Standard. Error	Beta		

1	(Constant)	209.272	136.133		1.537	.163
	Helmet F1	.760	.187	.820	4.057	.004
a. Dependent Variable: WFW F1						

The β, t and p values of F1 of /ə/ wearing helmet is given in the table. These values β=.760. t=4.057, p=.004 show that the independent variable (helmet) has significant relationship with dependent variable. It means that forensically relevant face covering helmet affects F1 of /ə/. The independent variable is directly associated with dependent variable, that is, change in independent variable is directly proportionate to dependent variable.

Table 2. Regression Coefficient Model 1Summary of F1 of Sound /ə/ wearing Helmet

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.820[a]	.673	.632	34.787
a. Predictors: (Constant), Helmet F1				

In table 2, the value of R is (.820). It shows that a strong positive relationship exists between independent and dependent variables included in this model. The R^2 (coefficient of determination) value is .673 which reveals that 67 % change in the dependent variable of the model is caused by the independent variable of the model.

Mask

Table 3. Regression Coefficient Model 2 of F1 of Sound /ə/ wearing Mask

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	283.716	103.649		2.737	.026
	Mask F1	.632	.137	.853	4.614	.002
a. Dependent Variable: WFW F1						

The values of β, t and p of F1 of /ə/ in table 3 for mask are β=.632. t=4.614, p =.002. These values show that relationship between independent and dependent variables is significant. It reveals that mask affects F1 of /ə/.

Table 4. Regression Coefficient Model 2 Summary of F1 of Sound /ə/ wearing Mask

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.853[a]	.727	.693	31.787
a. Predictors: (Constant), Mask F1				

The value of R (.853) in table 4 shows that a strong positive relationship exists between two variables included in the model. The value of coefficient of determination (R square) is .727, it means that 72 % change in the dependent variable of the model is caused by the independent variable of the model.

Niqab

Table 5. Regression Coefficient Model 3 of F1 of Sound /ə/ wearing Niqab

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	282.050	94.514		2.984	.017
	Niqab F1	.622	.122	.874	5.079	.001
a. Dependent Variable: WFW F1						

Table 5 shows β=.622. t=5.079, p =.001 values. It means that niqab affects F1 of /ə/. The significant relationship is found between independent and dependent variable.

Table 6. Regression Coefficient Model 3 Summary of F1 of Sound /ə/ wearing Niqab

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.874[a]	.763	.734	29.593
a. Predictors: (Constant), Niqab F1				

In table 6, the value of R .874 shows a strong positive relationship between two variables. The value R^2 (coefficient of determination) is .763which indicates that 76 % change in the dependent variable of the model is caused by the independent variables of the model

b) Analysis of F2 of Sound /ə/

Helmet

Table 7. Regression Coefficient Model 1 of F2 of Sound /ə/ wearing Helmet

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	190.760	419.293		.455	.661
	HELMET F2	.958	.301	.748	3.189	.013
a. Dependent Variable: WFW F2						

The values β=.958. t=3.189, p =.013 in table 7 show that the independent variable (helmet) has significant relationship with dependent variable. It means that helmet affects F2 of /ə/.

Table 8. Regression Coefficient Model 1 Summary of F2 of Sound /ə/ wearing Helmet

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.748[a]	.560	.505	128.935
a. Predictors: (Constant), HELMET F2				

The R value of .748 shows a strong positive relationship between two variables included in the model. The value R^2 (coefficient of determination) is .560, which shows that 56 % change in the dependent variable of the model is caused by the independent variable of the model.

Mask

Table 9. Regression Coefficient Model 2 of F2 of Sound /ə/ wearing Mask

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	217.309	179.443		1.211	.260
	mask f2	.865	.118	.933	7.324	.000
a. Dependent Variable: WFW F2						

The values of β=.865. t=7.324, p =.000 in table 9 show that forensically relevant face covering mask affects F2 of /ə/.

Table 10. Regression Coefficient Model 2 Summary of F2 of Sound /ə/ wearing Mask

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.933[a]	.870	.854	70.001
a. Predictors: (Constant), mask f2				

In table 10, the R value .933 shows positive relationship between two variables. The value R^2 (coefficient of determination) is .870. It shows that 87 % change in the dependent variable of the model is caused by the independent variable of the model.

Niqab

Table 11. Regression Coefficient Model 3 of F2 of Sound /ə/ wearing Niqab

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	14.102	157.330		.090	.931
	Niqab f2	1.016	.105	.960	9.640	.000
a. Dependent Variable: WFW F2						

The value of β=1.016. t=9.640, p =.000 show that forensically relevant face covering niqab affects F2 /ə/.

Table 12. Regression Coefficient Model 3 Summary of F2 of Sound /ə/ wearing Niqab

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.960[a]	.921	.911	54.707
a. Predictors: (Constant), Niqab f2				

In table 12, the value of R .960 shows a strong positive relationship between two variables. The value R^2 (coefficient of determination) is .921, which shows that 92 % change in the dependent variable of the model is caused by the independent variable of the model.

c) Analysis of Duration of Sound /ə/

Helmet

Table 13. Regression Coefficient Model 1 of duration of Sound /ə/ wearing Helmet

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	50.497	18.517		2.727	.026
	HELEMT D	.551	.165	.763	3.336	.010
a. Dependent Variable: D. WFW						

Table 13 shows the values β=.551. t=3.336, p =.010 for helmet which mean that significant relationship exists between the two variables. The forensically relevant face covering helmet affects duration /ə/.

Table 14. Regression Coefficient Model 1 Summary of duration of Sound /ə/ wearing Helmet

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.763[a]	.582	.529	9.740
a. Predictors: (Constant), HELEMT D				

In table 14, the R value (.763) reveals that a strong positive relationship exists between two variables. The value R^2 (coefficient of determination) is .582 which shows that 58 % change in the dependent variable of the model is caused by the independent variable of the model.

Mask

Table 15. Regression Coefficient Model 2 of duration of Sound /ə/ wearing Mask

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	50.648	55.317		.916	.387
	MASK D	.565	.513	.363	1.102	.303
a. Dependent Variable: D.. WFW						

The values of β=.565, t=1.102, p=.303 show that forensically relevant face covering mask doesn't affect duration /ə/.

Table 16. Regression Coefficient Model 2 Summary of duration of Sound /ə/ wearing Mask

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.363[a]	.132	.023	14.033
a. Predictors: (Constant), MASK D				

In table 16, the value R^2 (coefficient of determination) is .132. It means that 13 % change in the dependent variable of the model is caused by the independent variable of the model.

Niqab

Table 17. Regression Coefficient Model 2 of duration of Sound /ə/ wearing Niqab

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	55.610	35.782		1.554	.159
	D niqab	.509	.324	.485	1.570	.155
a. Dependent Variable: D.. WFW						

The values β .509, t 1.570 and P .155 of duration of /ə/ in table 17 for niqab show that niqab doesn't affect duration of /ə/.

Table 18. Regression Coefficient Model 3 Summary of duration of Sound /ə/ wearing Niqab

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.485[a]	.236	.140	13.168
a. Predictors: (Constant), D niqab				

In table 18, the value R^2 (coefficient of determination) is .236. It means that 23 % change in the dependent variable of the model is caused by the independent variable of the model.

d). Analysis of F1 of Sound /a:/
Helmet

Table 19. Regression Coefficient Model 1 of F1 of Sound /**a:**/ wearing Helmet

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	257.824	236.692		1.089	.308
	Helmet f1	.689	.317	.609	2.171	.062
a. Dependent Variable: WFW F1						

The values β=.689, t=2.17, p=.062 of F1 in table19 show that independent variable (helmet) has no significant relationship with dependent variable. It means that helmet doesn't affect F1 of /a:/.

Table 20. Regression Coefficient Model 1Summary of F1 of Sound /**a:**/ wearing Helmet

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.609[a]	.371	.292	57.028
a. Predictors: (Constant), Helmet f1				

In table 20, the R value .609 shows that a strong positive relationship doesn't exist between two variables included in model. The value R^2 (coefficient of determination) is .371 which shows that 37% change in the dependent variable of the model is caused by the independent variable of the model.

Mask

Table 21. Regression Coefficient Model 2 of F1 of Sound /**a:**/ wearing Mask

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	447.171	159.417		2.805	.023
	Mask F1	.415	.203	.585	2.041	.076
a. Dependent Variable: WFW F1						

The values β=.415, t= 2.041 and p=.076 show that mask doesn't affect F1 /a:/.

Table 22. Regression Coefficient Model 2 Summary of F1 of Sound /**a:**/ wearing Mask

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.585[a]	.342	.260	58.305
a. Predictors: (Constant), Mask F1				

In table 22, the R value .585 which shows that a strong positive relationship doesn't exist between two variables. The value R^2 (coefficient of determination) is .342. It means that 34% change in the dependent variable of the model is caused by the independent variable of the model.

Mask

Table 23. Regression Coefficient Model 3 of F1 of Sound /**a:**/ wearing Niqab

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	426.745	197.080		2.165	.062
	Niqab F1	.439	.251	.527	1.752	.118
a. Dependent Variable: WFW F1						

The values β=.439, t=1.752 and p=.118 of F1 of /**a:**/ in table 23 for niqab show that it doesn't affect F1 /a:/.

Table 24. Regression Coefficient Model 3 of F1 of Sound /**a:**/ wearing Niqab

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.527[a]	.277	.187	61.123
a. Predictors: (Constant), Niqab F1				

In table 24, the R value .527 which shows that a strong positive relationship doesn't exist between two variables included in model. The value R^2 (coefficient of determination) is .277 which shows that 27% change in the dependent variable of the model is caused by the independent variable of the model.

e). Analysis of F2 of Sound a:

Helmet

Table 25. Regression Coefficient Model 1 of F2 of Sound /**a:**/ wearing Helmet

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	507.004	286.416		1.770	.115
	HELMET F2	.668	.230	.716	2.903	.020
a. Dependent Variable: WFW F2						

The values β=.668, t=2.903 and P=.020 of F2 of / **a:** / in table 25 for helmet show that a significant relationship exists between two variables. It means that helmet affects F2 of /a:/.

Table 26. Regression Coefficient Model 1 of F2 of Sound /**a:**/ wearing Helmet

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.716[a]	.513	.452	88.301
a. Predictors: (Constant), HELMET F2				

In table 26, the R value (.716) shows that positive relationship exists between two variables included in model. The value R^2 (coefficient of determination) is .513 which shows that 51% change in the dependent variable of the model is caused by the independent variable of the model.

Mask

Table 27. Regression Coefficient Model 2 of F2 of Sound /**a:**/ wearing Mask

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	947.101	379.030		2.499	.037
	mask f2	.282	.274	.341	1.027	.334
a. Dependent Variable: WFW F2						

The values β=.282, t=1.027 and P=.334 of F2 of /**a:**/ in table 27 for mask show that there is no significant relationship between dependent and independent variable. It means that face covering mask doesn't affect F2 of /a:/.

Table 28. Regression Coefficient Model 2 Summary of F2 of Sound /**a:**/ wearing mask

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.341[a]	.117	.006	118.937
a. Predictors: (Constant), mask F2				

In table 28, the R value shows no significant relationship between two variables included in the model. The value R^2 (coefficient of determination) is .341. It means that 11% change in the dependent variable of the model is caused by the independent variable of the model.

Niqab

Table 29. Regression Coefficient Model 3 of F2 of Sound /**a:**/ wearing Niqab

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	484.212	525.773		.921	.384
	Niqab f2	.664	.409	.497	1.621	.144
a. Dependent Variable: WFW F2						

The statistics β=.664, t=1.621 and p=.144 of F2 of /**a:**/ in table 29 show that niqab doesn't affect F2 of /a:/.

Table 30. Regression Coefficient Model 3 Summary of F2 of Sound /**a:**/ wearing Niqab

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.497[a]	.247	.153	109.789
a. Predictors: (Constant), Niqab f2				

In table 30, the values of R and R^2 (coefficient of determination) show that there is no significant relationship between two variables included in the model. The value R^2 (coefficient of determination) is .247. It means that 24% change in the dependent variable of the model is caused by the independent variable of the model.

f). Analysis of Duration of Sound /a:/

Table 31. Regression Coefficient Model 1 of Duration of Sound /**a:**/ wearing Helmet

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	-93.727	68.567		-1.367	.209
	HELMET D	1.316	.268	.866	4.908	.001
a. Dependent Variable: D.. WFW						

The values (β=1.316, t=4.908 and p=.001 of duration of / **a:** / in table 31 show that forensically relevant face covering helmet affects duration of /a:/.

Table 32. Regression Coefficient Model 1 Summary of duration of Sound /**a:**/ wearing Helmet

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.866[a]	.751	.720	23.580
a. Predictors: (Constant), HELMET D				

The R value .866 shows a strong positive relationship between two variables included in model. The value R^2 (coefficient of determination) is .751. It means that 75% change in the dependent variable of the model is caused by the independent variable of the model.

Mask

Table 33. Regression Coefficient Model 2 of Duration of Sound /**a:**/ wearing Mask

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	315.208	75.332		4.184	.003
	MASK D	-.337	.335	-.335	-1.005	.344
a. Dependent Variable: D.. WFW						

The values β=-.337, t=-1.005 and p=.344 of duration of /**a:**/ in table 33 show that mask doesn't affect duration of /a:/.

Table 34. Regression Coefficient Model 2 Summary of Duration of Sound /**a:**/ wearing Mask

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.335[a]	.112	.001	44.497
a. Predictors: (Constant), MASK D				

In table 34, the values of R and R^2 show that there doesn't exist a strong positive relationship between two variables included in the model.

Niqab

Table 35. Regression Coefficient Model 3 of Duration of Sound /**a:**/ wearing Niqab

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	-60.272	104.622		-.576	.580
	D niqab	1.234	.427	.715	2.892	.020
a. Dependent Variable: D.. WFW						

The values β=1.234, t=2.892 and p=.020 of duration of /**a:**/ in table 35 show that niqab affects duration of /a:/.

Table 36. Regression Coefficient Model 3 Summary of Duration of Sound /**a:**/ wearing Niqab

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.715[a]	.511	.450	33.019
a. Predictors: (Constant), D niqab				

In table 36, the R value .715 reveals that there exists a strong positive relationship between two variables included in the model. The value R^2 (coefficient of determination) is .511. It means that 51% change in the dependent variable of the model is caused by the independent variable of the model.

Discussion

The β, t and p values of sound /ə/ showed that helmet, mask and niqab have significant effect on acoustic properties (F1, F2) of Pahari vowels but it did not affect duration. In case of /a:/, the statistics showed that mask and niqab don't have significant effect on F1, F2 and duration, but helmet has significant effect on F2 and duration. The central /ə/ is more effected than /a:/

Llamas *et al.* (2008) stated that the modifications on acoustic signal due to face wear are originated from two sources. Firstly, it is stated in different phonetic theories, like the source-filter theory of speech production given by Fant (1960), or quantal theory of speech by Stevens (Stevens, 1972; 1989; Stevens & Keyser, 2010), that the resultant acoustic signal may change due to smaller modification in articulatory gestures during speech production. Even when there is slight change in position of the articulators while speaking through face wear, it results in prominent changes in acoustic properties of sound produced. Secondly, acoustic facewear effects are due to physical obstruction found in the face of the speaker. The sound wave propagation is obstructed when any fabric or material covers the mouth as it will lost the sound energy of certain spectral component. Additional turbulence is created when air molecules hit any material outside the mouth. The degree of interference created by sound absorbing characteristics of face wears' material can also be found in this way (Clark *et al.*, 2007).

According to Flege et al. (1988) and McFarland and Baum (1995), articulatory configuration of consonants is more precise than vowels. The results of this study showed that face wears helmet mask and niqab affected F1, F2 of /ə/ and only helmet affected F2 of /a:/.

Conclusion

The study investigated the effects of face coverings (helmet, mask and niqab) on acoustic properties of Pahari central vowels /ə/ and /a:/. Two parameters, formant patterns (F1 and F2) and duration were analyzed by using Praat software. Regression analysis was used to analyze data statistically. The results showed: a) all the three face coverings (helmet, mask and niqab) significantly affected F1, F2 of /ə/; b) only helmet affected F2 of /a:/; c) none of the face coverings affected the duration of /ə/ and /a:/. The results suggest that face coverings can change the acoustic properties of speech. In future, more research is required on vowels to generalize the results.

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Appendix A

F1, F2 and Duration of sound /ə/

	WFW	helmet	Mask	Niqab
1MəF1	654	640	661	660
1MəF2	1226	1212	1249	1245
1MəD	103	111	112	113
2MəF1	735	665	779	714
2MəF2	1405	1177	1386	1382
2MəD	117	159	118	136
3MəF1	794	747	756	825
3MəF2	1392	1228	1285	1321
3MəD	136	113	108	105
4MəF1	782	741	781	743
4MəF2	1409	1401	1422	1406
4MəD	107	102	113	100
5MəF1	768	706	720	754
5MəF2	1433	1407	1433	1448
5MəD	118	117	120	120
1FəF1	732	778	752	807
1FəF2	1685	1621	1650	1616
1FəD	137	147	104	123
2FəF1	732	660	708	680
2FəF2	1671	1532	1699	1625
2FəD	109	115	109	106
3FəF1	731	690	669	743
3FəF2	1804	1429	1695	1720
3FəD	96	88	103	101
4FəF1	799	795	769	819
4FəF2	1485	1423	1425	1352
4FəD	101	86	90	89
5FəF1	890	822	936	933
5FəF2	1705	1455	1837	1724
5FəD	95	92	98	104

Appendex B

F1, F2 and Duration of /a:/

	WFW	helmet	Mask	Niqab
1Ma:F1	635	635	628	629
1Ma:F2	1165	1161	1200	1201
1Ma:D	3350	301	288	284
2Ma:F1	818	665	695	700
2Ma:F2	1235	986	1088	1203
2Ma:D	238	285	234	248
3Ma:F1	805	757	759	843
3Ma:F2	1325	1192	1332	1252
3Ma:D	136	238	234	254
4Ma:F1	753	749	799	747
4Ma:F2	1242	1247	1272	1253
4Ma:D	255	270	290	281
5Ma:F1	786	729	707	737
5Ma:F2	1406	1251	1375	1322
5Ma:D	221	246	213	223
1Fa:F1	772	779	804	820
1Fa:F2	1505	1380	1489	1494
1Fa:D	285	287	253	261
2Fa:F1	752	721	791	754
2Fa:F2	1281	1186	1296	1279
2Fa:D	193	219	202	216
3Fa:F1	696	759	824	857
3Fa:F2	1457	1254	1505	1294
3Fa:D	245	243	217	228
4Fa:F1	807	810	801	868
4Fa:F2	1249	1267	1355	1327
4Fa:D	237	231	239	213
5Fa:F1	879	830	987	866
5Fa:F2	1481	1465	1444	1189
5Fa:D	181	222	209	231