

EFFECTS OF FFP2 FACE MASKS ON CONSONANT IDENTIFICATION

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ABSTRACT

The COVID-19 pandemic has led most countries to recommend or mandate the use of face masks in public places. Although masks have been shown to reduce virus transmission, they also affect communication by attenuating speech sounds and concealing speakers' facial expressions and lip movements. Previous research examining adverse effects of face masks on speech perception has mainly focused on global measures of intelligibility. This study examined the effects of wearing face masks on consonant identification. Greek listeners identified 20 Greek consonants (embedded in VCV tokens) uttered with and without FFP2 face masks. The results showed that identification was significantly lower for consonants uttered with face masks than for consonants uttered without face masks, with female listeners outperforming male listeners in both tasks. Across genders and tasks, voicing was the most salient perceptual feature, place of articulation was the least salient feature and manner of articulation was in between.

Keywords: Identification, consonants, FFP2 face masks.

1. INTRODUCTION

Successful communication requires perceiving speech in various listening environments. Under ideal conditions and for adults with normal hearing, speech perception in one's native language generally approaches ceiling performance (although there are cases where two phonemes may be confused with one another, e.g., /f/ and /θ/ for English listeners, see [1]; /v/ and /ð/ for Greek listeners, see [2]). When communication takes place in adverse listening conditions, however, listeners often have difficulty in understanding speech, as shown by numerous studies comparing different types of maskers, signal-to-noise ratios (SNRs), and language backgrounds, among others [3, 4, 5].

The COVID-19 pandemic has added yet another difficulty in communication as most countries have recommended or mandated the use of face masks in public places to reduce virus transmission [6]. Wearing a face mask alters the acoustic features of

speech and conceals speakers' facial expressions and lip movements resulting in decreased speech intelligibility, depending on mask type (cloth, surgical, respirator) [7, 8, 9, 10]. [7] for example, evaluated different mask types showing that most masks had little acoustic effect below 1 kHz, but they attenuated higher frequencies by different amounts depending on the fabric, shape and fit of the mask.

Previous research examining adverse effects of wearing face masks on speech perception has mainly focused on global measures of intelligibility at word or sentence level. This study examined the effects of face masks on consonant identification thus removing any word frequency effects. Greek listeners identified 20 Greek consonants embedded in aCa tokens uttered with and without FFP2 face masks. FFP2 masks, widely used in Europe, filter at least 94% of all aerosols, including COVID-19, offering similar protection to America's N95 and China's KN95 masks [11]. The study complements work in [2], examining the identification of 20 Greek consonants in quiet and in two types of background noise, a competing talker at an SNR of -6 dB and an 8-speaker babble at an SNR of -2 dB. The results in [2] showed that Greek listeners achieved excellent results in quiet across consonants except for fricatives /θ/ and /ð/. Consonant identification was significantly lower in the two noise conditions, with the 8-speaker babble having a larger deteriorating effect in listeners' identification compared to the competing speaker (despite the difference in SNR). Across listening conditions, voicing was more resistant to noise than manner of articulation, which was in turn more resistant to noise than place of articulation (for similar results, see [12, 13]).

The goals of the current study were therefore to (a) examine the effects of wearing face masks on consonant identification (b) pinpoint the most difficult consonants for Greek listeners, especially in the masked condition and (c) compare the salience of voicing, place, and manner of articulation. Both male and female listeners were tested because of gender-related anatomical and functional differences of the brain and the auditory system [14] that could be affecting performance. For example, females generally outperform males in verbal fluency, perceptual speech, and fine motor skills while males are better in spatial and working memory [15, 16, 17].

2. METHOD

2.1. Participants

Participants were 14 native speakers of Greek (7 m, 7 f) with a mean age of 28 years (age range 19 to 45 years). They all reported normal hearing and no language impairment.

2.2. Stimuli

Stimuli consisted of aCa tokens (stressed on the second syllable) containing the stops /p/, /b/, /t/, /d/, /k/, /g/, the fricatives /f/, /v/, /θ/, /ð/, /s/, /z/, /x/, /ɣ/, the nasals /m/ and /n/, the liquids /l/ and /r/, and the affricates /ts/ and /dz/. Stimuli were recorded by four native speakers of Greek (2 m, 2 f) with and without wearing FFP2 masks (MASKED vs. UNMASKED condition, respectively) for a total of 160 stimuli (20 consonants × 4 speakers × 2 conditions).

2.3. Procedure

Testing was administered in TP software [18]. Following each stimulus presentation, participants indicated which consonant they heard by clicking on a computer screen one of 20 consonant options written in Greek orthography.

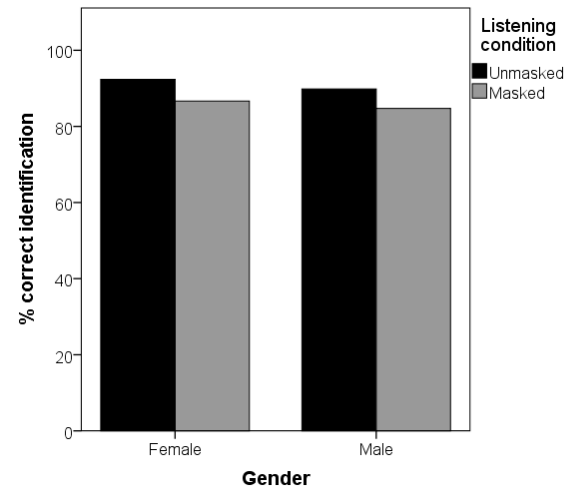


Figure 1: Mean percent correct identification across Greek consonants by female and male listeners in UNMASKED and MASKED condition.

3. RESULTS

Figure 1 shows percent correct identification scores for female and male listeners in each condition. Both groups achieved higher scores in the UNMASKED condition compared to the MASKED condition. For female listeners, mean identification dropped from 92.4% to 86.7% correct, respectively. For male

Stim.	Response																			
	p	b	t	d	k	g	ts	dz	f	v	θ	ð	s	z	x	ɣ	m	n	l	r
p	97	2	1																	
b		97									3									
t	3	3	81						3	3	3			3	3					
d				73		9			3		15									
k			3		97															
g		3				85										12				
ts							90	7		3										
dz							3	94								3				
f									60		34		6							
v										85	3	12								
θ								3	3	94										
ð				3					6	6	84									
s													100							
z														100						
x															100					
ɣ						6										94				
m																	100			
n																		100		
l																			100	
r																2			3	95

Table 1: Greek consonant confusion patterns in UNMASKED condition. Percentages have been pooled over participants and genders. Responses less than 3% are not shown.

Stim.	Response																			
	p	b	t	d	k	g	ts	dz	f	v	θ	ð	s	z	x	γ	m	n	l	r
p	97		3																	
b	3	94									3									
t	13		78		9															
d				71							29									
k			3		94				3											
g						70					2				28					
ts							94	6												
dz							9	91												
f				3					44		53									
v										81		19								
θ				13					19		69									
ð				3						6	16	63				9				
s													100							
z														100						
x															100					
γ																97				3
m																	94	6		
n			3															94	3	
l																			100	
r																9				91

Table 2: Greek consonant confusion patterns in MASKED condition. Percentages have been pooled over participants and genders. Responses less than 3% are not shown.

listeners, mean identification dropped from 89.8% to 84.7% correct, respectively. A mixed ANOVA on identification scores with Gender as between-subjects factor and Condition as within-subjects factor showed a significant main effect of Condition, $F(1, 12) = 121.6, p < .001$, confirming that the use of FFP2 face masks lowered consonant identification. Female listeners outperformed male listeners across conditions, but the differences between the two groups did not reach significance nor did the group \times condition interaction (the small sample size of the study may have masked the effect).

Confusion matrices in the two conditions are shown in Tables 1 and 2 (pooled over genders). Identification scores in UNMASKED condition (Table 1) ranged from 60% to 100% correct. The most problematic consonant was /f/ (confused with /θ/ 34% of time), followed by /d/, /t/, /ð/, /g/, and /v/ (all below 90% correct). Identification scores in MASKED condition (Table 2) ranged from 44% to 100% correct. The most problematic consonant was, again, /f/ (confused with /θ/ 53% of time), followed by /θ/ and /ð/ (both below 70% correct).

Table 3 shows percent correct identification of Greek consonants as a function of the three dimensions along which consonants are characterized, namely voicing, place of articulation, and manner of articulation. These were coded as

Condition	Dimensions		
	Voicing	Place-of-articulation	Manner-of-articulation
UNMASKED	97.7	92.5	95.8
MASKED	97.5	90.9	95.3

Table 3: Mean percent correct identification for voicing, place-of-articulation, and manner-of-articulation in two conditions pooled over genders.

follows: Voicing had two values, voiced and voiceless. Place of articulation had four values, labial, dental, alveolar, and velar. Manner of articulation had five values, plosive, fricative, affricate, liquid, and nasal. Across genders and conditions, voicing was the most salient perceptual feature, place of articulation was the least salient feature and manner of articulation was in between.

4. DISCUSSION

This study examined the effects of wearing face masks on consonant identification. Greek listeners identified 20 Greek consonants uttered with and without FFP2 face masks. The stimuli were aCa tokens so that listeners could not make use of lexical information when identifying consonants. Results showed that wearing face masks significantly lowered identification. Across conditions, fricatives were found to be the most problematic consonants to

identify. This is consistent with previous research in Greek and other languages showing that fricatives are generally difficult to perceive [1, 2]. Across genders and tasks, voicing was the most salient perceptual feature, place of articulation was the least salient feature and manner of articulation was in between [12, 13].

Female listeners outperformed male listeners in both conditions, but differences did not reach significance. Given the anatomical and functional differences between males and females [14] and the superiority of females in speech perception tasks reported in some studies (e.g., [17]), it would not be surprising if differences reached significance using a larger sample size (but note that there are studies in the literature reporting no differences in performance between males and females, e.g., [19]).

A 5% mask-induced decrease in mean identification accuracy is not expected to create much difficulty to normal-hearing individuals in otherwise ideal listening conditions. The decrease is larger, however, in the presence of background noise [10], when noise is combined with poor room acoustics (e.g., in school classrooms [20]) and when listeners are D/deaf or hard of hearing [21]. In those situations, clear speech production and use of transparent face masks that do not block visual information can significantly improve communication [10].

6. ACKNOWLEDGMENTS

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