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Abstract

This study investigates self-perceptions of voice-related handicap, quantified by means of the Voice Handicap Index (VHI), as a function of facemask use in the general working population during the COVID19 outbreak. Each VHI item was answered twice in a raw; the first answer referred to the condition of not wearing a facemask (henceforth, the *Without* condition) and the second to facemask use (henceforth, the *With* condition). VHI scores were collected via *Google Forms* (Google, Mountain View, California), targeting two groups of speakers, Portuguese (n = 261) and Spanish (n = 297). For each group, a Wilcoxon test was carried out to compare VHI scores between *With* and *Without* conditions. In addition, a Mann-Whitney test was used to compare groups for each condition. Results suggested that VHI overall scores and scores for all dimensions were higher for the *With* condition, for both Portuguese and Spanish speakers. When comparing groups of speakers, differences were found for functional and emotional dimensions, for both *With* and *Without* conditions. No differences were found for the total score for the *With* condition. It seems that self-perceived voice-related handicap is higher when using a facemask, independently of the speaker's sociocultural background. Thus, VHI total scores for Portuguese and Spanish speakers were combined and differences between *With* and *Without* facemask use conditions were calculated. A multivariate regression model suggested that 2.5% of VHI total score increase while using a facemask could be associated with sex, smoking habits and professional level. Female smokers who use their voices for prolonged hours at work (e.g., teachers, lawyers, sales people) have a

higher VHI total score when wearing a mask. Future voice-related health interventions should consider the need for addressing preventive strategies towards speaking behaviours leading to vocal fatigue and vocal effort as a consequence of compulsory facemask use, especially with respect to female professional voice users who smoke.

Key words: COVID19; Voice handicap index; Facemask use; Portuguese speakers; Spanish speakers.

1. Introduction

The use of facemasks to reduce the risk of airborne transmission of SARS-CoV-2 (COVID19) has been compulsory, from 2020 until, at least, 2021, in public spaces in European countries [1]. The use of this personal protective equipment has been reported to affect oral communication in many ways, namely concerning speech intelligibility [2], facial cues in human social interactions [3], emotional reading [4] and voice production [5].

Both surgical and filtering facepiece (FFP2) mask types seem to restrict speech intelligibility for listeners, especially in noisy environments and when speakers have a foreign accented [6]. The literature reports a reduction of about 3 to 12 dB in the frequency range between 2 to 8 kHz, with the FFP2 type, an European equivalent to the N95 facemasks wore in USA, offering the greatest attenuation [5,7–10]. According to recent studies, the low-pass filter effect of facemask use compromises the perception of several groups of phonemes, especially those with spectral peaks within 2 to 8 kHz, such as voiceless fricatives (Maryn et al., 2021). This effect seems particularly important when concerning languages rich in these consonants, such as Portuguese [11].

Speech comprehension has also been reported to be impaired in association with facemasks due to the substantial reduction of visual cues in oral communication. For example, Maltese individuals perceive a reduction in voice clarity and intensity [12]. In addition, lip reading is not an option when wearing a facemask. This might constitute a substantial drawback not only for those who are hearing-impaired, but also for children during stages of language development and students in a classroom [3,13,14].

Besides speech perception, voice production also seems to be affected by facemasks. Speakers report difficulties in coordinating breathing with speech when using N95 masks [15]. In addition to reports of lack of oxygen, voice projection and vocal fatigue have been pinpointed as major contributors to self-perceptions of vocal distress [12]. For example, in

Brazil individuals requiring facemask use during their professional activities, symptoms of vocal fatigue are more common as compared to individuals who wear a facemask during "essential activities" [16]. These effects have been associated with changes in speaking habits. Slowing down the speaking rate and increasing vocal loudness constitute examples of most common reported adaptative behaviours [17].

Habitual loud speech is well known to increase the risk of phonotrauma; however, such risk has not yet been completely understood with regard to facemask use during the pandemic. From a recent systematic review on effects of facemask use on different dimensions, effects on perceived vocal health are described to be assessed in only one study [18]. This was an investigation on the prevalence of self-perceived voice handicap during COVID19 outbreak in Chile, measured by means of the short version of the *Voice Handicap Index* (VHI-10). The results suggested that the VHI-10 scores during COVID19 are higher in healthcare professionals as compared with pre-COVID19 scores for the general population [19].

Voice impairment affects the quality of a person's life in many ways [20]. Besides the functional impact on working ability and employment opportunities, voice impairment can also affect social activities due to limited communication skills [21–23]. Such restrictions would also have a direct impact on a person's affective response to voice impairment [24]. The perceived impacts on functional, physical, and emotional domains are assessed by the VHI [25]; therefore, it seems relevant to use this scale when investigating the long-term effects of facemask use on self-perceptions of voice handicap, not only in health professionals, but also in the general population.

The present study aims at investigating self-perception of voice-related handicap as a function of compulsory facemask use during COVID19 outbreak. We hypothesise that speakers perceive a higher vocal handicap when using a facemask. As to date, voice-related handicap has been investigated mainly with respect to essential professionals; the current

study includes all types of professions. In addition, because effects of facemask use differ across speakers [5] and across phonemes [7], self-perceptions of voice-related handicap were compared between two populations of speakers, i.e., Portuguese and Spanish.

2. Materials and methods

2.1 Participants and study design

A comparative observational descriptive study was carried out. Participants were recruited through the authors' pre-existing personal contacts, via e-mail, social networks, and word of mouth. Inclusive criteria included: to be aged 18 or over, with no medically diagnosed hearing impairment, no restrictions to understand nor give an informed consent and a native Portuguese/ Spanish speaker. Only participants giving an informed consent were included.

2.2 Data collection

Data was collected from the middle of October 2020 until the middle of January 2021. Validated versions of both Portuguese and Spanish VHI were used. This particular questionnaire was chosen because it is the most conventional self-filled form of assessing voice-related handicap [26]. In addition, it has been translated and validated into both Portuguese and Spanish languages [27,28].

The same procedure was followed for both Portuguese and Spanish data collection. The VHI was anonymously filled in online using *Google Forms* (Google, Mountain View, California). For each of the 30 items, participants chose the most appropriate answer concerning frequency of experience of a given voice description or voice effect on life, at the present moment, using a Likert scale (0: never; 4: always). This was repeated in two consecutive conditions: first, for the case of not wearing a facemask (henceforth, the *Without*

condition) and, second, when wearing a facemask (the *With* condition). This order of presentation of items was followed to ensure that participants would have as a reference, the more habitual condition, i.e. no facemask use.

Participants were also enquired about: (i) facemask type most frequently worn; (ii) total number of daily hours of use; and (iii) commonly associated discomfort. Other questions addressed general health, history of medically diagnosed voice pathologies, vocal hygiene routines, and sociodemographic information, such as age, sex, smoking habits, and professional occupation.

2.3 Statistical analysis

Both descriptive and inferential analysis were carried out; for nominal data, descriptive statistics included relative and absolute values. Normal distribution of continuous quantitative variables was inspected by running a Shapiro-Wilk test; as a result, median and interquartile ranges were used to describe quantitative variables. For comparing VHI scores between conditions (i.e., *With* and *Without*), a Wilcoxon test was carried out. A Mann-Whitney U test was performed to compare VHI scores between Portuguese and Spanish speakers for both conditions. A stepwise multivariate-regression analysis was carried out to assess whether there was a statistical association between the difference in VHI overall scores for the *With* and for the *Without* conditions (henceforth, overall VHI_{diff}) and the independent variables of interest: age, sex, smoking habits, professional occupation, nationality, facemask type and its hours of use. Independent variables that were categorical were transformed into dummy variables, following the statistical recommendation described elsewhere [29]. All statistical analysis were carried out using SPSS version 24 (IBM Corporation, Armonk, NY).

3. Results

3.1 *Sample characteristics*

From a total of 642 respondents, 301 (47%) were Portuguese and 341 (53%) were Spanish native speakers. For the purpose of assessing self-perceptions of voice-related handicap with respect to facemask use, only participants reporting absence of current medically diagnosed voice pathologies were included. This yielded a total of 261 and 297 Portuguese and Spanish participants, respectively (40.7% and 46.3% of the total respondents). For professional occupation, participants were grouped according to the classification system based on voice use and vocal demand described elsewhere [30]. This type of classification ranges from highly skilled professional voice users, such as singers (Level I), to professionals whose work does not depend on vocal quality (Level IV). Table 1 summarises sample characteristics for the participants.

Table 1. Summary of participants characteristics, displayed also by nationality.

Participants without vocal pathology	**Portuguese, *n* (%)**	**Spanish, *n* (%)**	**Total (n%)**
Age			
Mean (SD)	44.8 (15.9)	40.3 (11.5)	42.39 (13.9)
Sex			
Male	97 (37.2)	79 (26.6)	176 (31.5)
Female	164 (62.8)	217 (73.1)	381 (68.3)
Prefer not to answer	0	1 (0.3)	1 (0.2)
Smoker			
Yes	52 (19.9)	56 (18.8)	108 (19.3)
No	209 (80.1)	241 (81.1)	450 (80.6)
Professional occupation according to voice use and vocal demand*			
Level I	28 (10.7)	3 (1)	31 (5.6)
Level II	88 (33.7)	135 (45.5)	223 (40)
Level III	27 (10.3)	39 (13.1)	66 (11.8)
Level IV	103 (53.6)	89 (46.4)	192 (34.4)
Type of facemask			
Surgical	126 (48.3)	143 (48.1)	269 (48.2)
FFP2	16 (6.1)	69 (23.2)	85 (15.2)
Other	60 (23)	85 (28.6)	145 (26)
Combined use of different facemasks	59 (22.6)	0	59 (10.6)

Facemask use to work			
Yes	177 (67.8)	199 (67)	376 (67.4)
No	81 (31)	90 (30.3)	171 (30.6)
Daily facemask use in hours			
Mean (SD)	5.7 (6.8)	5.7 (3.2)	5.7 (5.2)

* Professional classification based on voice use and vocal demand proposed by Koufman & Isaacson (1991).

3.2 VHI scores

VHI scores (individual dimensions and overall), were non-normally distributed for both conditions (according to the Shapiro-Wilk normality test). Therefore, scores were compared between *With* and *Without* conditions using a non-parametric Wilcoxon signed-rank test. The results indicated that, for all dimensions and for the overall score, both Portuguese and Spanish speakers perceived higher voice-related handicap when using a facemask (see Table 2).

Table 2. Results of the Wilcoxon sign-rank test, comparing dimensions and overall score for the VHI between conditions (i.e., facemask use, the *With* condition and non-use, the W*ithout* condition), for both Portuguese and Spanish speakers.

VHI scores	**Portuguese speakers**				Wilcoxon signed-rank test	**Spanish speakers**				Wilcoxon signed-rank test
	Without		*With*			*Without*		*With*		
	Mdn	IQR	Mdn	IQR		Mdn	IQR	Mdn	IQR	
Funtional	3	4	11	10	z = -13.366*	5	6	13	10	z = -14.465*
Physical	3	5	11	13	z = -13.081*	3	6	11	12	z = -14.098*
Emotional	0	2	3	7	z = -9.977*	1	4	4	6	z = -11.095*
Total	7	10	25	29	z = -13.465*	10	12	28	25	z = -14.558*

N.B.: * statistical significance ($p < 0.001$); Mdn = median; IQR = interquartile range.

Given that VHI scores (dimensions and overall) were statistically different for both *With* and *Without* conditions in Portuguese and in Spanish populations, a Mann-Whitney U test was carried out to compare VHI scores between Portuguese and Spanish speakers in both conditions. The results suggest that, for the *Without* condition, Spanish speakers perceived a

higher overall voice-handicap as compared to Portuguese; however, this difference was not observed for the *With* condition (see Table 3).

When comparing overall VHI_{diff} between speakers, i.e., the difference in the VHI total score between *With* and *Without* conditions, no significant differences could be found [$Z = -0.7$; $p = 0.484$]. The VHI mean total score for the *With* condition had a similar relative increase for both Portuguese (16%) and Spanish (17%) speakers. In addition, for both groups of speakers, dimensions showed similar VHI mean percent of increase: 6.55% to 7.57% for the functional dimension; 6.84% and 6.33% for the physical; and 2.74% and 3.23% for the emotional. For each dimension, the items receiving the highest score in the 0 to 4 frequency scale were similar in both Portuguese and Spanish populations (see Figure 1).

Table 3. Summary results of the Mann-Whitney U test comparing VHI dimensions and overall scores between Portuguese and Spanish speakers.

VHI scores	*Without*	*With*
Funtional	$U = -2.947$; $p = 0.003$*	$U = -3.415$; $p = 0.001$*
Physical	$U = -0.250$; $p = 0.803$	$U = -0.742$; $p = 0.458$
Emotional	$U = -4.172$; $p < 0.001$*	$U = -2.910$; $p = 0.004$*
Total	$U = -2.710$; $p = 0.007$*	$U = -1.679$; $p = 0.093$

N.B.: * statistical significance ($p < 0.005$).

< Please insert Figure 1 about here>

Figure 1. Distribution of ratings of the highest score in the 0 to 4 frequency scale (0 = never; 4 = always) used in VHI_{diff} for both Portuguese (black) and Spanish (grey) speakers. The left most graph corresponds to score 4 for each item presented in the functional dimension, whereas middle and most right graphs correspond to physical and emotional dimensions, respectively.

Given the above results, a multiple linear regression analysis was carried out using a dataset that included both Portuguese and Spanish overall VHI_{diff}. The result estimated three models (see Table 4). The first contained the independent variable *profession* (adjusted r^2 = 0.012); the second added the variable *sex* (adjusted r^2 of 0.019); and the third included the independent variables *profession*, *sex* and *smoker* (adjusted r^2 = 0.025). The third model provided the highest association, with 2.5 % of the variation in overall VHI_{diff} explained by the type of profession, the sex and smoking habits.

Table 4. Summary of unstandardised and standardised multiple regression coefficients for the three models obtained when testing the statistical association between the difference of VHI overall score with and without facemask use.

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	*t*	*p*
1	(Constant)	18.114	1.092		16.589	0.000
	Profession	4.747	1.723	0.116	2.755	0.006
2	(Constant)	11.354	3.200		3.548	0.000
	Profession	4.598	1.718	0.113	2.677	0.008
	Sex	4.044	1.800	0.095	2.247	0.025
3	(Constant)	19.211	4.989		3.851	0.000
	Profession	4.380	1.716	0.107	2.553	0.011
	Sex	4.094	1.795	0.096	2.281	0.023
	Smoker	-4.350	2.124	-0.086	-2.049	0.041

N.B.: * statistical significance ($p < 0.005$).

4. Discussion

The current investigation concerned self-perceptions of voice-related handicap associated with compulsory facemask use during COVID19 pandemic outbreak, between October 2020 and January 2021. As the impact of facemask use on phonation may differ across speakers [5] and across phonemes [7], two populations of non-dysphonic speakers were investigated, i.e., Portuguese and Spanish, using the respective validated translations of the

VHI [27,28]. All responses were obtained online, following previous recommendations on the benefits of using online surveys during outbreaks of rapidly evolving infectious diseases [31].

For both populations of speakers, all VHI items were investigated for both *Without* and *With* facemask use conditions, the latter assessed by adding "when wearing a facemask" at the end of each VHI item. Such procedure was followed to provide respondents with the same and the most habitual reference for self-perception of voice-related handicap i.e., the *Without* condition. This could be understood as a possible methodological limitation of the current investigation. However, this seems not to be the case. The overall mean VHI scores for the *Without* condition are in agreement with previously reported VHI overall scores for both Portuguese and Spanish non-dysphonic populations [27,28]. The Portuguese participants showed a mean overall VHI score of 11.4 (± 13.8), which is closed to the 10.5 (± 1.8) reported by Guimarães & Abberton (2004). For the Spanish population, participants reported a mean overall VHI score of 13.2 (± 12.8), which is also closed to the 8.1 (± 9.8) reported by Núñez-Batalla et al. (2007). The higher standard deviations found in our results could be explained by the substantial higher number of non-dysphonic participants (n= 261, as compared to the 56 previously studied Portuguese speakers; and n = 297, as compared to the 38 previously investigated Spanish speakers).

The overall mean VHI scores for the *With* condition showed values similar to those reported by previous studies when assessing self-perceived voice handicap in dysphonic voices. According to Guimarães & Abberton (2004), VHI overall scores in dysphonic Portuguese voices are 34.4 (± 3.2), a value comparable to the one found in the present investigation for the *With* condition (30.8 ± 21.62). For Spanish speakers, according to Núñez-Batalla et al. (2007), dysphonic voices can have an overall VHI score between 40.9 and 48.2, depending on whether the dysphonia is organic or functional. In the present investigation, overall mean VHI scores for the *With* condition were below these values;

however, given that the studied population did not have a dysphonic voice, one may argue that 33.77 (± 22.47) corresponds to a high perceived voice handicap.

Previous studies have found that effects of facemask use may vary according to speakers [5]. In order to investigate this, comparisons of effects of facemask use in two different populations of speakers, i.e. Portuguese and Spanish, were made. Results suggested significant differences between these two groups except for the physical dimension for the *Without* condition. For the *With* condition, differences were also found except for the physical dimension and the overall total scores. These results were not surprising. First, with regard to the *Without* condition, it is well document that VHI scores are different for Portuguese and Spanish speakers [27,28]. Second, the physical dimension failed to show significant differences because questions concerned voice production rather than aspects of communication and social interactions. These are reflected in the other two dimensions of the VHI, and are clearly more dependent on the cultural background of the respondent. Third, the overall VHI scores did not reveal significant differences between Portuguese and Spanish populations.

Given these results, the difference in the overall VHI score between *With* and *Without* conditions was calculated for the whole sample of speakers. The results indicated a significant increase in VHI scores (i.e., more self-perceived voice handicap with regard to facemask use) for all dimensions and total score. This increase was within the magnitude of 6.55% to 7.57% for functional, 6.84% and 6.33% for physical, and 2.74% and 3.23% for emotional dimensions, and between 16% and 17% for the overall VHI score, in Portuguese and Spanish speakers, respectively. Thus, one may argue that the effects of facemask use are more pronounced with regard to verbal communication. This assumption can be corroborated by the distribution of ratings for the highest score in the 0 to 4 frequency scale (0 = never; 4 = always). The VHI_{diff} was higher for the item "People have difficulty understanding me in a

noisy room" (functional dimension) in both Portuguese and Spanish speakers. This item was also reported to be the one receiving higher VHI ratings of frequency in health professionals when wearing a facemask [19]. Increased values of VHI scores when using a facemask can be associated with higher vocal fatigue and vocal effort [19], both symptoms associated with louder speech in noisy environments. The results of this investigation suggested that such symptoms may be extendable also to other professionals besides healthcare workers. This is not surprising, bearing in mind that the COVID19 has forced the use of facemasks during all professional and daily life activities, in both Portugal and Spain.

Previous investigations suggest that effects of facemask use on the voice may vary across phonemes [7]. In addition, type of mask and total daily time of use can also contribute to higher VHI-10 scores [19]. The results of the present study seem to point at a different direction. No statistical association was found between VHI_{diff} scores and nationality, type of facemask and daily hours of facemask use. Instead, factors that could predict higher differences between *With* and *Without* conditions were sex, professional level and smoking habits. Being a female level II professional (i.e., a teacher, public speaker, politician, call centre worker, sales person, judge or lawyer), who smokes, seems to be associated with a higher self-perception of voice-related handicap when wearing and not wearing a facemask. These results are in accordance to previous literature. First, it is well documented that being a female increases the risk of developing a voice-related health problem [32]. Voice pathologies are higher in women than in men: 46.3% as compared to 36.9%, respectively [33]. Research suggests that anatomical and histological differences could account for this higher incidence. Females have shorter vocal folds, that vibrate almost twice as fast than male vocal folds [32]. Although the smaller vibrating amplitude of female vocal folds may protect them from being exposed to a higher risk of damage due a higher number of vibrations [32], female vocal folds have less hyaluronic acid in the layers of the vocal folds more exposed to collision forces [34].

This, in addition to the smaller concentrations of collagen found in female's lamina propria [34], expose women to a higher risk of a voice disorder as compared to men [32]. Also, the complexity of the endocrinological female reproductive system can account for a higher exposure to risk of vocal problems as compared to men [32,34]. For example, sex steroid hormonal variations during puberty, the menstrual cycle, pregnancy, and menopause have been pinpointed as life stages during which vocal changes may occur [35,36]. Possible explanations include i) similarities found between the histological response of the mucosa of the vocal folds and the mucosa of the cervix to sex hormes [37–39], and ii) the presence of sex steroid hormonal receptors at different sub-units of the vocal folds [40]. Second, professionals that require extended periods of voice use, such as teachers, are also exposed to higher risks of vocal hazards [41]. Finally, a recent systematic review on effects of smoking on voice revealed substantial alterations to voice function [42]. In the current investigation, we found that female smokers were particularly sensitive to alterations to their voices as compared to males. This result seems to corroborate previous findings suggesting that answering the VHI helps female smokers to become more aware of the potential risks of smoking to vocal health [43].

5. Conclusions

The present investigation contributes to the understanding of self-perceptions of voice handicap with regard to facemask use. Speakers, independently of being Portuguese or Spanish, perceive a higher voice-related handicap when wearing a facemask. Being a female smoker who requires extended periods of voice use seems to contribute to higher self-perceptions of voice handicap. With the prolonged compulsory use of facemask use in most European countries, modifications to speaking behaviors are expected. To guarantee maintenance of vocal health during compulsory facemask use at work, future voice-related

health interventions should be considered. These should address preventive strategies towards the development of speaking behaviors that may lead to vocal fatigue and vocal effort, targeting particularly those who required prolonged use of voice at work.

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