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Influence of the COVID-19 mask on speech

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Abstract
COVID-19 has marked a watershed for society, drastically changing the way people interact with each other. In the current pandemic situation, the use of masks is an indispensable element to limit the spread of the virus. However, masks can significantly impact the spoken message and therefore, the intelligibility of speech. Different types of masks, classified according to their protection degree, can be found in the market, being the most frequently used the surgical masks and FFP2. This paper focuses on the assessment of their effect on people's speech. The attenuation of sound pressure level produced in each case was analysed as well as the influence on the directivity of the source. At the same time, a spectral analysis of the speech was carried out for different phonemes. Finally, by means of speech audiometry tests, the level of intelligibility was determined. The variations produced with respect to the sound produced by a speaker under normal conditions showed the influence of the mask on speech communication.

Keywords: speech intelligibility, mask, COVID-19, audiometry, directivity

1 Introduction

COVID-19 has marked a turning point in society, drastically changing the way people interact with each other. In this situation, the use of masks is essential to limit the spread of the virus. Currently, in Spain, its use is mandatory in any public space. However, this protective equipment could significantly affect the quality of the speech, which will result in a decrease in intelligibility.

Different works could be found in the literature regarding this problem. One of the first was proposed by Palmiero et al. [1]. The authors analysed the effect of the mask on intelligibility using the Speech Transmission Index, STI [2]. With the appearance of COVID-19, the number of works in this area has increased significantly. Pörschmann et al. [3] analyse its acoustic effects by establishing both transmission loss and directivity index in different cases. Similarly, Magee et al. [4] and Truong et al. [5] study the effects of wearing a mask on speech perception. Also, Bottalico et al. [6] and Choi [7] focus on the effects on speech intelligibility in teaching. In addition to analysing the influence on speech level and speech directivity, they carry out different psychoacoustic tests in order to establish a correlation between objective parameters and the listener's perception or intelligibility. In all cases, the authors highlight a clear influence of the mask on the intelligibility of the speech. However, given the disparity in the methods used to assess the effects and the complexity of the problem (physical and psychological aspects are involved), further study is needed.

This research focuses on the study of the acoustic properties of the most commonly used COVID-19 masks and their influence on speech intelligibility.

2 Methodology

2.1 Materials

The sanitary mask is a protective element whose purpose is to prevent and limit the spread of viruses. This element, placed "blocking" the mouth, will act as an air filter and therefore, as a resistive component to the air flow. As a consequence, the pressure waves will be altered producing a variation in the sound emitted depending on the characteristics of the mask.

Different models of masks, classified according to the degree of protection, can be found in the market. The most frequently used during the COVID-19 pandemic have been the hygienic or cloth mask, the surgical mask and the FFP2 (figure 1). Their acoustic characteristics will be analysed in this paper.

(a) Surgical (b) FFP2 (c) Fabric

Figure 1. Types of masks analysed during the tests.

2.2 Procedure for the acoustic characterisation of samples

The acoustic characterisation of the samples was carried out on the basis of different laboratory tests. Firstly, the influence of the mask on the sound pressure emitted by the speaker was determined by establishing the attenuation level, obtained comparing the sound pressure level with and without the mask at a distance of 0.5m. A broadband signal (white noise) was emitted by means of a dummy head connected to a loudspeaker through an inner tube (similar to the trachea). The different masks were placed on the front of the face (see figure 1). To avoid a possible influence of background noise, the measurements were carried out in a semi-anechoic chamber

Secondly, impedance tube measurements were carried out following the scheme shown in figure 3. Masks were placed at the end of the tube, without any end termination. From the pressure recorded by both microphones, the impedance of each material was obtained. Its real part represents an indicator of the flow resistance.

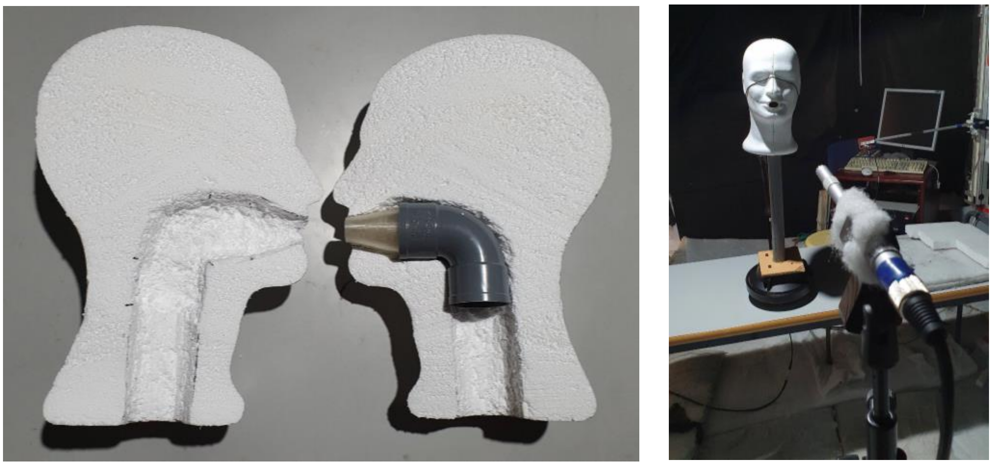

Figure 2. Experimental set-up for acoustic characterisation.

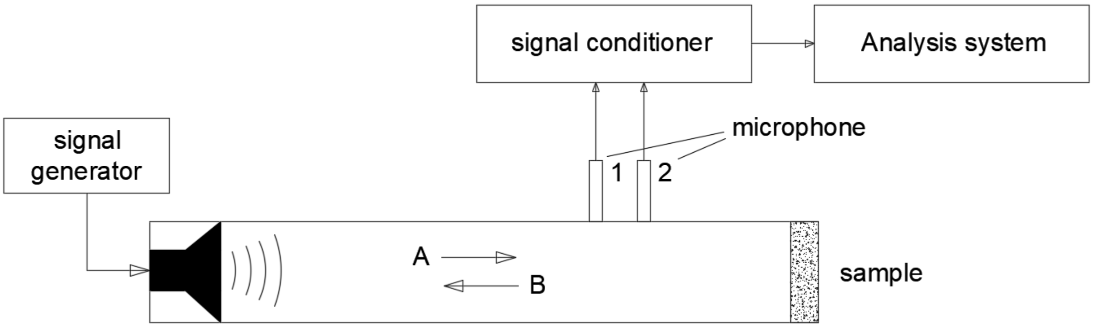

Figure 3. Experimental set-up used to obtain the acoustic impedance of the masks

Thirdly, the directivity pattern of each sample was determined using an automatic turntable. The emission without mask was used as a reference for further comparison.

2.3 Procedure for determining the influence of the mask on speech intelligibility

In order to establish the influence of the mask on the spoken message, first of all, a spectral analysis of different sound registers was carried out. This test allowed to identify those phonemes whose sound behaviour may suffer a greater alteration due to the use of the mask.

At the same time, in order to facilitate the calculation of certain parameters related to speech intelligibility, the impulse response of the system was obtained for the surgical and FFP2 masks. The subsequent signal analysis was based on the STI parameter [2], which provides a numerical value for the quality of the communication channel. The percentage of consonant articulation loss, %ALcons, was also determined. In both cases, measurements were performed in a semi-anechoic chamber with a background noise level of 43 dB (simulated by a loudspeaker excited with a white noise signal).

Finally, based on speech audiometry tests, the listener's level of intelligibility was established for each sample. The speech audiometry tests were based on the listener’s hearing difference from a list of words with a proportion of phonemes and syllabic structures typical of spoken Spanish [8]. In this case, the study consisted of a test of distinctive features. Each participant was provided with a list of words with two columns (extract from the list shown in table 1). Each row of these columns corresponded to a pair of words with certain distinguishing features (e.g. dardo – tardo, Spanish). One of the words from each pair was played through a flat-response headset. The listener indicated on the form the perceived word in each case. The same procedure was applied to audio recordings with surgical and FFP2 masks to determine their influence on the correct answers rate.

Table 1. Extract of words included in speech audiometry tests (Spanish) [8].

Vague			Baje	Yema			Chema
Dardo			Tardo	Mudo			Nudo
Día			Tía	Pata			Papa
Baña			Vaya	Pecho			Techo
Deme			Debe	Toro			Poro
Rama			Rana	Tuerca			Puerca

3 Results and discussion

3.1 Analysis of the influence of the mask on the sound pressure signal

Results show a clear decrease in the sound pressure level, with values above 5 dB for frequencies from 2,250 Hz (figure 4). This behaviour results in a reduction of the overall sound pressure level emitted by the speaker. In a reverberant environment with the presence of background noise, the loudness of the message and its intelligibility may be compromised. Similar results were obtained for the impedance tube measurements (figure 5). The differences for FFP2 sample may be due to a difference in the orientation of the fabric with respect to the sound wave in both configurations (perpendicular, oblique).

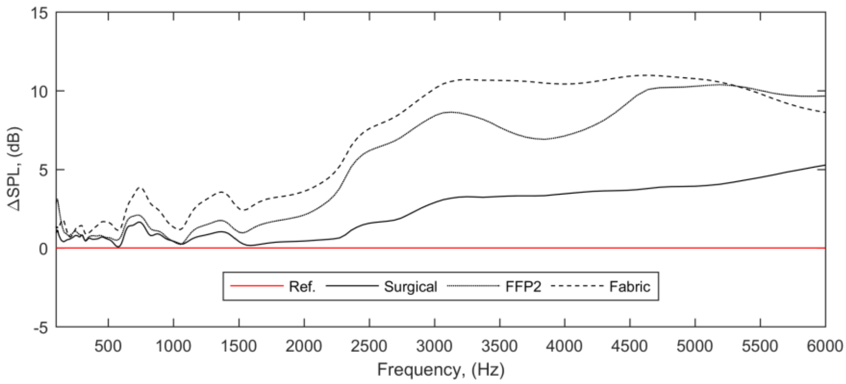

Figure 4. Attenuation level obtained for the different masks. Reference corresponding to situation without mask.

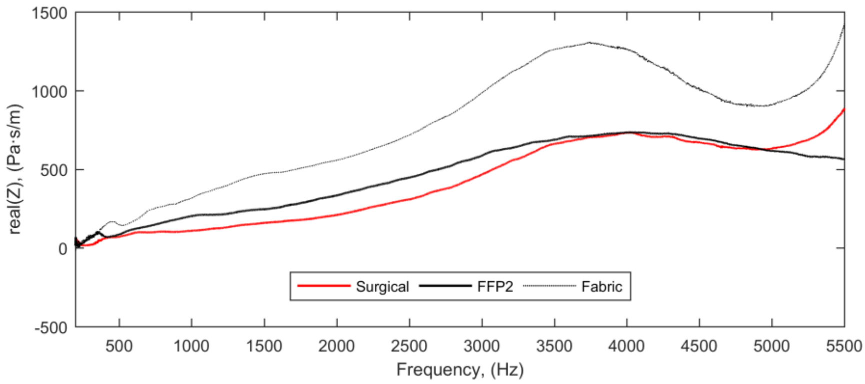

Figure 5. Real part of the acoustic impedance for different masks.

Also, directivity tests show slightly different patterns depending on the sample, especially at frequencies above 4 kHz (figure 6).

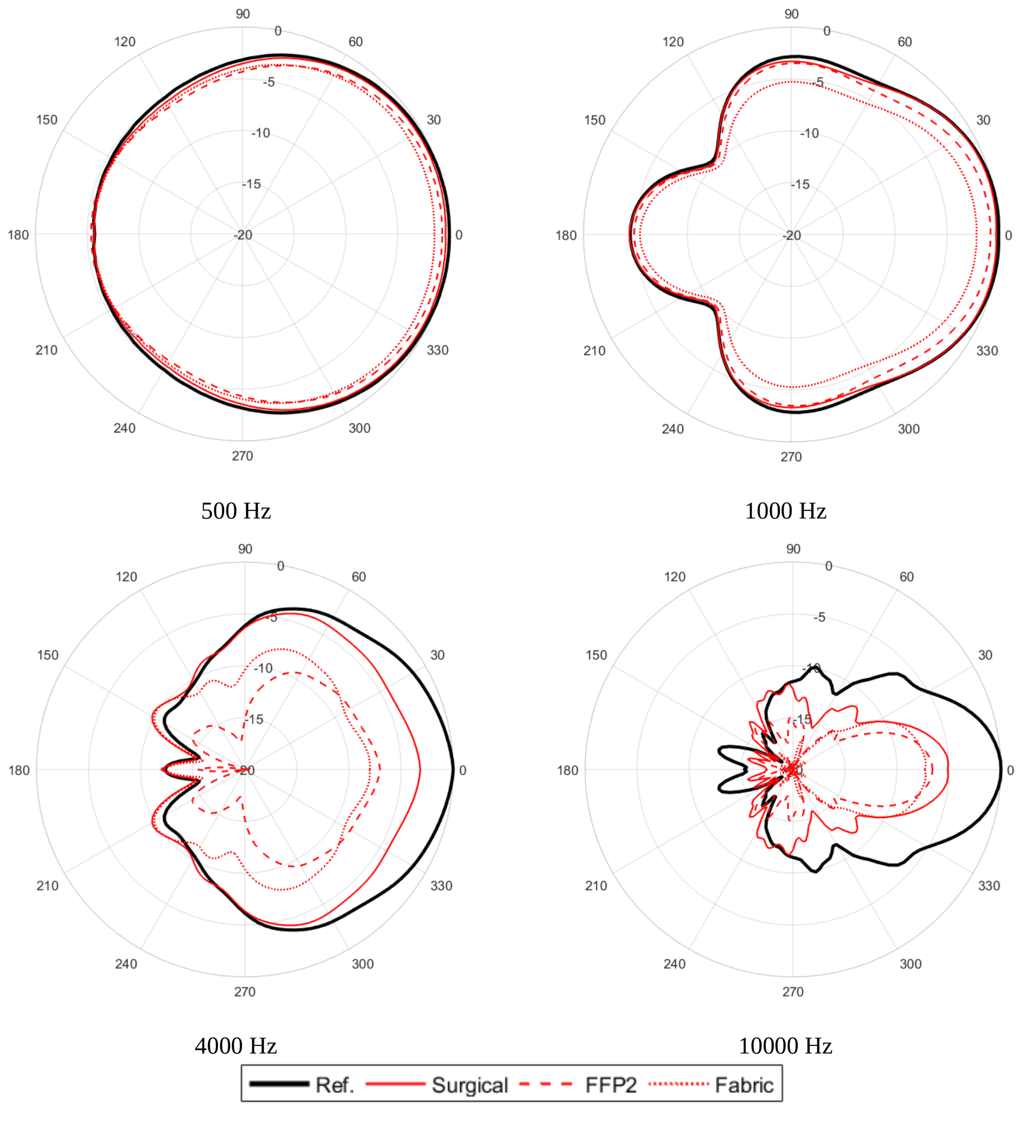

Figure 6. Directivity pattern at different frequencies.

3.2 Analysis of the influence of the mask on the spoken message

From a spectral analysis of speech, we can determine those frequency components that will be most affected by the presence of the mask. The study was carried out using the experimental set-up indicated in the previous section (figure 2), emitting different words. As observed in the attenuation curve, high frequencies (from 2,250 Hz) suffered a drop in amplitude. This behaviour could affect certain consonants such as 's' or 'g', whose pronunciation will lose sonority. Figure 7 shows, as an example, the spectrograms obtained for the Spanish words *dardo* (dart) and *segar* (mow) for different samples. The difference between the pressure obtained without mask and with mask in each case is also shown.

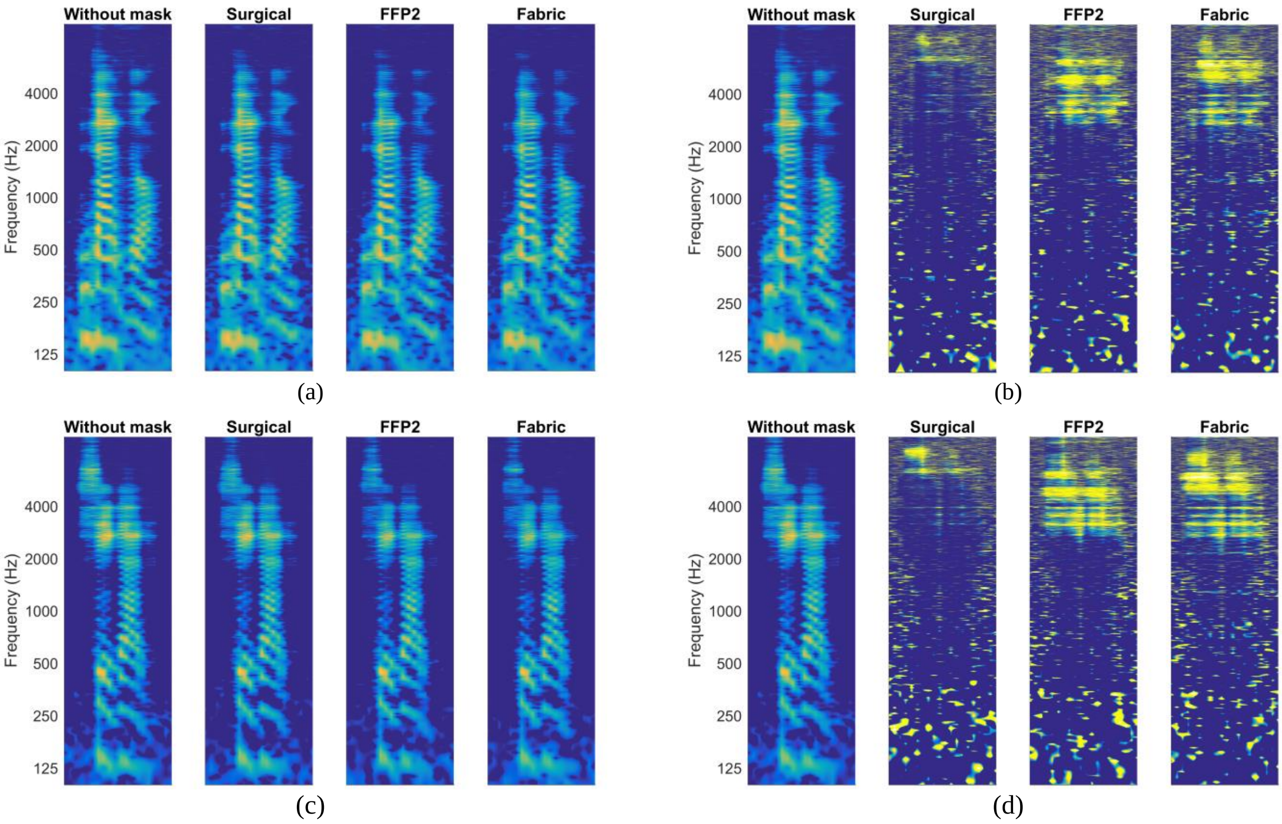

Figure 7. Spectrogram corresponding to the words: (a) *dardo* - dart; (c) *segar* - mow; for four different configurations. Left: spectrograms (a, b). Right: difference (b, d).

On the other hand, from the impulse response of the system, the STI parameter values shown in table 2 were obtained for male and female voices and for surgical and FFP2 masks.

Table 2. STI values obtained for different mask types

	Without mask	Surgical	FFP2
Male	0,67	0,65	0,63
Female	0,73	0,70	0,69

Similarly, it was possible to establish the degree of intelligibility based on the percentage of loss of consonant articulation, %ALcons. This parameter, used in the assessment of the sound quality of architectural spaces, indicates the average percentage of consonants that may not be understood. It should be noted that consonants are an indispensable element for the intelligibility of the spoken message. With regard to the effect of the masks, this parameter shows an increase in losses of approximately one percentage point for both the surgical model and the FFP2 compared to the system without mask (8% with mask - 7% without mask).

The speech audiometry tests show that the attenuation introduced by the FFP2 mask leads to a considerable decrease in speech intelligibility (27.6% of hits - figure 8). The same behaviour was obtained for the surgical mask, but in this case, the decrease in the percentage of hits was not so severe. This behaviour coincides with that observed for parameters such as STI and %ALcons. It should be noted that the results obtained are provisional, as only 6 speech audiometries were performed.

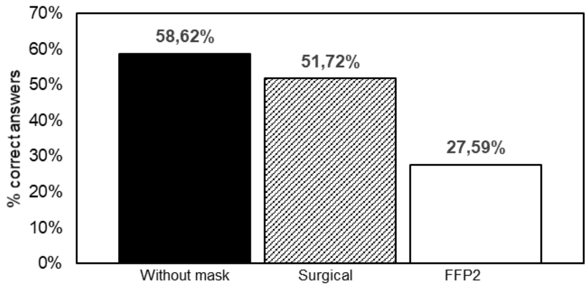

Figure 8. Percentage of success in speech audiometry tests.

4 Conclusions

In the present work, the influence of the mask on speech and its possible implications were analysed. Firstly, different acoustic tests were carried out in order to obtain the parameters that best described the effect produced on the sound waves. At the same time, a perception test was carried out to assess the possible influence of the mask on the intelligibility of speech.

The acoustic tests showed a significant difference in the sound pressure level produced by a speaker with and without mask. For the surgical type, we found a difference of more than 3 dB for frequencies above 3 kHz. This value increased for FFP2 mask, with more than 5 dB (10 dB in some cases) for frequencies above 2,500 Hz. This behaviour will affect the loudness of the message and therefore, its intelligibility. Parameters such as STI or %ALcons corroborated this trend. Attenuation is also reflected in the spectrogram, where certain consonants (e.g. ‘s’ and ‘g’) suffer a variation. The results were verified by means of speech audiometry tests. In this case, a higher percentage of correct answers was obtained for messages recorded without mask (58.5% vs. 27.8% with FFP2). The results are in agreement with those obtained by other authors in the literature.

It should be noted that any negative effect on speech caused by the lack of mobility of the lips was not considered, so that the actual effect on intelligibility may be greater.

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References

[1] Palmiero, A. J.; Symons, D.; et al. (2016). Speech intelligibility assessment of protective facemasks and air-purifying respirators. J. Occup. Environ. Hyg. Vol. 13(21). pp. 960–968.

[2] Steeneken, H. J. M., and Houtgast, T. (1980). A physical method for measuring speech transmission quality. J. Acoust. Soc. Am. Vol. 67. pp. 318–326.

[3] Pörschmann, Ch.; Lübeck, T.; Arend, J. M. (2020). Impact of face masks on voice radiation. J. Acoust. Soc. Am. Vol. 148. pp. 3663-3670.

[4] Magee, M.; Lewis, C.; et al. (2020). Effects of face masks on acoustic analysis and speech perception: Implications for peri-pandemic protocols. JASA. 148. pp. 3562-3568.

[5] Lan-Truong, T.; Beck, S. D.; Weber, A. (2021). The impact of face masks on the recall of spoken sentences. J. Acoust. Soc. Am. Letter to the editor. Vol. 149. pp. 142-144.

[6] Bottalico, P.; Murgia, S.; et al. (2020). Effect of masks on speech intelligibility in auralized classrooms. J. Acoust. Soc. Am. Vol. 148. pp. 2878-2884.

[7] Choi, Y. (2021). Acoustical measurements of masks and the effects on the speech intelligibility in university classrooms. Applied Acoustics. Vol. 180. 108145.

[8] Cárdenas, M.; Marrero Aguiar, V. (1994). Cuaderno de logoaudiometría. Universidad Nacional de Educación a Distancia.