# COVID-19 and Deafness: Impact of Face Masks on Speech Perception

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## Abstract

**Background** The COVID-19 pandemic has made wearing face masks a common habit in public places. Several reports have underlined the increased difficulties encountered by deaf people in speech comprehension, resulting in a higher risk of social isolation and psychological distress.

**Purpose** To address the detrimental effect of different types of face masks on speech perception, according to the listener hearing level and background noise.

**Research Design** Quasi-experimental cross-sectional study.

**Study Sample** Thirty patients were assessed: 16 with normal hearing [NH], and 14 hearing-impaired [HI] with moderate hearing loss.

**Data Collection and Analysis** A speech perception test (TAUV) was administered by an operator trained to speak at 65 dB, without a face mask, with a surgical mask, and with a KN95/FFP2 face mask, in a quiet and in a noisy environment (cocktail party noise, 55 dB). The Hearing Handicap Index for Adults (HHI-A) was administered twice, asking subjects to complete it for the period before and after the pandemic outburst. A 2-way repeated-measure analysis of variance was performed.

**Results** The NH group showed a significant difference between the no-mask and the KN95/FFP2-mask condition in noise ($p = 0.01$). The HI group showed significant differences for surgical or KN95/FFP2 mask compared with no mask, and for KN95/FFP2 compared with surgical mask, in quiet and in noise ($p < 0.001$). An increase in HHI-A scores was recorded for the HI patients ($p < 0.001$).

**Conclusion** Face masks have a detrimental effect on speech perception especially for HI patients, potentially worsening their hearing-related quality of life.

**Keywords**
- COVID-19
- SARS-CoV-2
- mask
- communication
- hearing
- deafness

Among the changes that the coronavirus disease (COVID-19) pandemic has introduced in our habits, wearing face masks to limit viral transmission in public places has been one of the most common (Eikenberry et al., 2020).[1] Alteration in oral communication is a noteworthy side effect of face mask usage, since these devices impede lip-reading and filter higher voice frequencies to varying extents in relation to the mask model (Atcherson et al., 2017; Chodosh et al., 2020).[2,3]

Hearing-impaired individuals are particularly exposed to the risk of social limitations and subsequent adjunctive emotional burden due to speech-perception deficits (Trecca

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et al., 2020).[4] Deaf patients experience further difficulties in noisy and stressful environments, such as hospitals and health care settings (Chodosh et al., 2020).[3] In this pandemic phase, the problem gains collective relevance owing to the high prevalence of hypoacusis, with an estimated disabling hearing loss (HL) around 5% worldwide (World Health Organization, 2020).[5]

Several systems have been developed to facilitate communication, such as transparent face masks and real time speech-to-text transcription applications; however, while their adoption is quite common among health-care personnel, the same does not apply for daily contexts (Chodosh et al., 2020; West et al., 2020).[3,6]

The aim of the present study was to evaluate how speech perception is affected in subjects with different hearing threshold levels, when the speaker speaks without a mask, or uses either a surgical mask or a filtering mask (KN95/FFPN2), and comparing the results in a silent and noisy environment. Moreover, the Italian version of the Hearing Handicap Inventory for Adults (HHI-A) was administered to assess the impact of COVID-19 preventive measures on hearing-related quality of life in this cohort (Monzani et al., 2007).[7]

## Materials and Methods

### Study Design, Setting and Participants

In this prospective study, adult patients older than 18 years who consecutively accessed the audiological unit of our tertiary referral center (Otorhinolaryngology Unit, Cattinara University Hospital, Trieste, Italy) between October 20 and 29, 2020 were enrolled. The study was approved by the University of Trieste Health Sciences Institutional Review Board (No. 108/2020). Written informed consent was obtained from all participants. All procedures involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study followed the "Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)" reporting guideline (von Elm et al., 2007).[8]

Demographic and audiological characteristics were collected for descriptive purposes. All patients were provided with both N99/FFP3 and surgical face masks to reduce the risk of potential contagion.

Exclusion criteria were pure-tone average (the average of 0.5-, 1-, 2-, and 4-kHz thresholds; PTA) in the better ear $> 70$ dB, and any degree of cognitive impairment (evaluated with the Montreal Cognitive Assessment) or a current/previous history of mental illness or psychopharmacological therapy (Santangelo et al., 2015).[9]

Participants were assigned to one of two groups according to the PTA in the better ear:

- "Normal"-hearing (NH) group: patients with a PTA $< 25$ dB in the better ear;
- Hearing-impaired (HI) group: patients with a PTA between 40 and 70 dB in the better ear.

### Audiological Tests and Hearing-Related Quality-of-Life Assessment

All the audiological tests were conducted in a double-walled sound-treated booth (Mercury Electrical Acoustics, certified UNI EN ISO 8253–1:2010).

Pure-tone thresholds were measured for all participants at the octave frequencies from 250 to 8000 Hz using a diagnostic two-channel audiometer (Madsen Astera[2] GN Otometrics A/S, Denmark) with supra-aural earphones (TDH-39p; Telephonics, Farmingdale, NY).

For the purposes of this study, materials for the speech test were taken from a routinely used national standardized text (Burdo et al., 1995).[11] Among 12 lists of 10 sentences each, made up of 6 or 7 disyllabic words of common use, the operator (S.R.) randomly selected 6 lists for each patient. Randomization was performed by means of random number generation (Urbaniak & Plous, 2013).[12] The operator read the sentences inviting the patient to repeat them. For each list, a word-recognition score (WRS) was generated as a percentage of correctly repeated words relative to the total.

The selected lists were read by the operator in 6 different conditions:

1. without a face mask;
2. wearing a surgical face mask (Polypropylene YY/T 0969)
3. wearing a KN95/FFP2 face mask (Goldshield GB 2626).

Since cloth masks come in different types of tissues and layers, we tested only surgical and KN95/FFP2 masks designed for medical use that respect international standards, guaranteeing uniformity and comparability during the various situations of signal presentation.

Each condition was repeated in quiet and in noise: a 55-dB cocktail-party noise generated by the audiometer was reproduced by a loudspeaker placed above the operator's head. Comparisons between the WRSs obtained in quiet and noise were conducted within the NH and HI groups.

To minimize variability in test administration, the speech-recognition test was always administered by the same operator (S.R.), an adult Italian female speaker who had a neutral Italian accent. The operator was trained to speak at 65 dB using speech analysis software (Multi-Speech™, Model 3700; Computerized Speech Laboratory, CSL™ 4500; KayPENTAX, PENTAX Medical Company, New Jersey, USA) until the target range of $65 \pm 2$ dB was achieved for reading an entire list of sentences.

The participants were seated at a fixed distance of 1.5 m away from the operator at 0° azimuth and 1.5 m away from the loudspeaker at 45° azimuth. The operator sat in the double-walled room, directly below the loudspeaker during the procedure. The signal was delivered directly by the operator, while the background cocktail party sounds were reproduced by the loudspeaker.

For what concerns the hearing-related quality of life assessment, the Italian version of the HHI-A was administered twice, instructing participants to first refer to the pre-pandemic period and then to the same situations after mask wearing had become mandatory in public spaces (Monzani et al., 2007).[7] The questionnaire consists of 25 multiple-choice questions (13 concerning the emotional domain, 12 the socio-situational domain) investigating whether a hearing problem causes social limitations or psychological distress. The patient can answer "Yes" (4 points), "Sometimes" (2 points), or "No" (0 points). The overall scores were calculated as the sum of points for the two subdomains (emotional and socio-situational): higher scores correspond to worse hearing-related quality of life. The overall results and subscales were calculated and compared for both the NH and HI group.

### Statistical Analysis

Categorical variables were expressed as count (percentages). The normal distribution of the continuous variables was evaluated with the Shapiro-Wilk test and continuous variables were expressed as mean (standard deviation [SD]) or median (interquartile range [IQR]), as appropriate.

A 2-way repeated-measure analysis of variance was used to assess the effects of different face masks (no face mask vs surgical face mask vs KN95/FFP2 face mask) and environment (quiet vs noise) on WRS according to the hearing-level group, as well as to compare pre-pandemic vs post-pandemic HHI-A scores in the two groups. Post-hoc *t*-tests used Bonferroni adjustments for multiple comparisons. Standard errors (SE) and 95% confidence intervals (95% CI) are reported together with the difference of the mean for multiple comparisons.

All statistical analyses were performed using SPSS Version 26 (IBM Corp., Armonk, NY, USA). The level of significance for all tests was set at $p < 0.05$.

## Results

### Patients

A total of 32 participants were enrolled for the study. Two of them had a PTA of 30 and 32.5 dB in the better ear. Their performances were comparable with those of the NH patients; however, they were excluded owing to the insufficient sample size to form a separate group. Thirty patients were finally included: of these, 16 patients (53.3%) formed the NH group (mean age = 49.7 [19.6]; 8 males, 8 females; no one used amplification aids; mean unaided PTA = 11.9 [11.4] dB in the better ear, 18.9 [13.7] dB in the worse ear), and 14 (46.7%) formed the HI group (mean age = 68.8 [16.0]; 4 males, 10 females; 4 used no amplification, 6 used bilateral hearing aids, and 4 used bimodal amplification with cochlear implant and hearing aid; mean unaided PTA = 51.6 [16.5] dB in the better ear, 63.6 [20.8] dB in the worse ear).

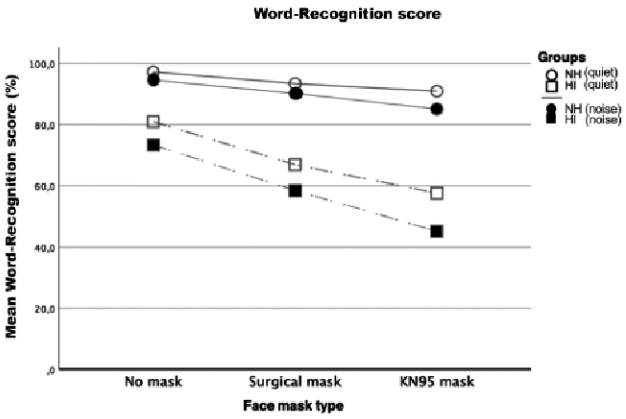


**Fig. 1** Mean Word-Recognition Scores (%) according to the type of face mask worn and environment; quiet and noisy environments are marked with open and filled symbols, respectively. NH = "normal"-hearing group. HI = hearing-impaired group.

### Speech-Recognition Test

►**Fig. 1** reports the mean WRSs wearing no mask, a surgical face mask and a KN95/FFP2 face mask, both in a quiet and in a noisy environment. The detrimental effect on WRSs of the surgical and KN95/FFP2 face masks, noisy background, and hearing loss is depicted. Statistical details are reported in the following sections.

### Multivariate Analysis

Multivariate analysis showed a significant effect for face masks, face masks × hearing group interaction, environment, and face masks × environment interaction; contrariwise, no significant effect emerged from the environment × group interaction and for the face mask × environment × group interaction. Detailed results are reported in ►**Table 1**.

### Normal Hearing Group

Multiple comparisons of WRS reveal that face masks had a significant effect in noise ($F_{2,27} = 4.688$, $p = 0.02$, $\eta p^2 = 0.26$, power = 0.74) but not in quiet ($F_{2,27} = 2.568$, $p = 0.10$, $\eta p^2 = 0.16$, power = 0.47).

**Table 1** Results of the multivariate analysis

| Factor | F | ηp2 | Power | p-value |
|---|---|---|---|---|
| Face mask | $F_{1.460,40.886} = 52.051$ | 0.65 | 1.00 | $< 0.001^*$ |
| Face mask × group | $F_{1.460,40.886} = 14.740$ | 0.35 | 0.99 | $< 0.001^*$ |
| Environment | $F_{1,28} = 22.688$ | 0.45 | 1.00 | $< 0.001^*$ |
| Environment × group | $F_{1,28} = 3.825$ | 0.12 | 0.47 | 0.06 |
| Face mask × environment | $F_{1.685,47.183} = 76.098$ | 0.12 | 0.62 | $0.03^*$ |
| Face mask × environment × group | $F_{1.685,47.183} = 0.144$ | 0.005 | 0.07 | 0.83 |

The F factor represents the variance between the sample means. Subscript numbers indicate the adjusted degrees of freedom. ηp2 is an effect size measure. * $p < 0.05$.

Looking in detail at the comparisons between mean WRSs in noise, the only significant difference was recorded-between the no-face-mask condition vs the KN95/FFP2-face-mask condition (9.5, SE = 3.0, 95% CI = 1.7–17.2, $p = 0.01$). No significant differences were found between the no-face-mask vs surgical-face-mask condition (4.4, SE = 2.0, 95% CI = –0.6–9.4, $p = 0.10$) or between the surgical- vs KN95/FFP2-face-mask condition (5.1, SE = 2.1, 95% CI = –0.4–10.5, $p = 0.07$).

### Hearing-Impaired Group

Face masks showed a significant effect both in quiet ($F_{2,27} = 23.651$, $p < 0.001$, $\eta p^2 = 0.64$, power = 1.00) and in noise ($F_{2,27} = 27.992$, $p < 0.001$, $\eta p^2 = 0.68$, power = 1.00).

In quiet, a worse mean WRS was recorded in the surgical-face-mask vs no-face-mask comparison (–14.0, SE = 2.5, 95% CI = –7.8––20.3, $p < 0.001$), in the KN95/FFP2- vs no-face-mask comparison (–23.4, SE = 3.4, 95% CI = –31.9––14.9, $p < 0.001$), and in the KN95/FFP2- vs surgical-face-mask comparison (–9.3, SE = 1.9, 95% CI = –14.3––4.4, $p < 0.001$).

Analogous results are reported in noise: surgical mask vs no face mask (–14.9, SE = 2.4, 95% CI = –21.1––8.7, $p < 0.001$), KN95/FFP2 vs no face mask (–28.1, SE = 3.7, 95% CI = –37.6––18.6, $p < 0.001$), and KN95/FFP2 vs surgical face mask (–13.2, SE = 2.6, 95% CI = –19.9––6.5, $p < 0.001$).

### Hearing-Related Quality of Life

Results of HHI-A scores and pairwise comparisons are reported in ►**Table 2**. HHI-A scores concerning the post-pandemic period showed a worsening trend in the overall domain and in the emotional and socio-situational subdomains in each group of patients; however, only in the HI group was the difference significant ($p < 0.001$, $p = 0.001$, $p = 0.002$, respectively) (►**Fig. 2**).

### Overall HHI-A Scores

A significant effect on the HHI-A overall scores was seen for the pandemic outburst ($F_{1,28} = 21.877$, $p < 0.001$, $\eta p^2 = 0.44$, power = 1.00) and for the pandemic × hearing-level group interaction ($F_{1,28} = 5.251$, $p = 0.03$, $\eta p^2 = 0.16$, power = 0.60). The pairwise comparisons showed significant differences in mean scores for the HI group but not for the NH group ($p < 0.001$, $p = 0.07$, respectively; ►**Table 2**).

### Emotional HHI-A Subdomain

A significant effect was recorded for the pandemic outburst ($F_{1,28} = 12.999$, $p = 0.001$, $\eta p^2 = 0.32$, power = 0.94) and for the pandemic × hearing-level group interaction ($F_{1,28} = 5.872$, $p = 0.02$, $\eta p^2 = 0.17$, power = 0.65) on the emotional subdomain. Only the HI group showed a significant difference at the pairwise comparisons ($p = 0.001$; ►**Table 2**).

### Socio-Situational HHI-A Subdomain

The pandemic outburst had a significant effect on the socio-situational domain ($F_{1,28} = 15.897$, $p < 0.001$, $\eta p^2 = 0.36$, power = 0.97), which did not emerge from the pandemic × hearing-level group interaction ($F_{1,28} = 2.102$, $p = 0.16$, $\eta p^2 = 0.07$, power = 0.28).

A difference between average pre- and post-pandemic scores regarding socio-situational domains is reported for both groups; however, the statistical significance was reached only for the HI group but not for the NH group ($p = 0.002$, $p = 0.06$, respectively; ►**Table 2**).

## Discussion

Since the COVID-19 pandemic spread worldwide, several studies have highlighted the adjunctive difficulties in communication faced by hearing-impaired individuals as a result

**Table 2** Results of the hearing handicap inventory for adults, before and after the pandemic outburst

| Group by hearing level | HHI-A | Before/after pandemic | Mean (SD) | Difference of mean (SE) | 95% CI | p-value |
|---|---|---|---|---|---|---|
| NH group | Overall | Before | 8.6 (13.0) | 2.1 (1.1) | −0.2–4.4 | 0.07 |
| | | After | 10.7 (16.2) | | | |
| | Emotional subscale | Before | 3.8 (5.8) | 0.6 (0.6) | −0.7–1.8 | 0.36 |
| | | After | 4.3 (7.2) | | | |
| | Socio-situational subscale | Before | 4.8 (7.5) | 1.6 (0.8) | 0.0–3.1 | 0.06 |
| | | After | 6.3 (9.9) | | | |
| HI group | Overall | Before | 45.2 (22.1) | 6.2 (1.4) | 3.4–9.0 | <0.001* |
| | | After | 51.3 (24.4) | | | |
| | Emotional subscale | Before | 19.8 (11.7) | 2.8 (0.7) | 1.3–4.3 | 0.001* |
| | | After | 22.7 (12.7) | | | |
| | Socio-situational subscale | Before | 25.3 (11.0) | 3.3 (1.0) | 1.4–5.3 | 0.002* |
| | | After | 28.7 (12.3) | | | |

Abbreviations: 95% CI, 95% confidence interval; HHI-A, Hearing Handicap Inventory for Adults; HI group, hearing impaired group; NH group, normal hearing group; SD, standard deviation; SE, standard error.
Bonferroni adjustments were applied for multiple comparisons.
*$p < 0.05$.