Do face masks affect the way we hear?

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ABSTRACT:

Aim: The aim of the study was to assess whether wearing a face mask behind the ears has an effect on the understanding of speech and the perception of surrounding sounds.

Materials and methods: Auditory perception was assessed using verbal noise audiometry in two clinical conditions: without a face mask and with a face mask. To assess auditory perception ability, two parameters were measured: word recognition score (WRS) and sound intensity at maximum WRS.

Results: Without wearing face masks, the maximum WRS values for the study group ranged from 75% to 100%, with 52% of respondents achieving a WRS of 100%. The highest WRS for the subjects wearing masks ranged from 80% to 100%, with 32% of subjects achieving a WRS of 100%.

Conclusions: Wearing face masks does not change speech recognition scores. This may indicate a greater role of psychosocial aspects of hearing difficulties during the COVID-19 pandemic.

KEYWORDS: COVID-19, hearing, protective masks, word recognition score

ABBREVIATIONS

COVID-19 – coronavirus disease 2019
SIN – speech-in-noise
SNR – signal to noise ratio
WRS – word recognition score

INTRODUCTION

During the COVID-19 pandemic, the need to comply with restrictions, which included the mandatory covering of the mouth and nose, revealed an inherent problem of auditory perception and speech understanding [1]. Publications released since then have indicated that approximately 14% of respondents did not report problems with the perception of sounds, while moderate to severe comprehension issues were reported by over 50% of respondents. Furthermore, 55.9% of subjects had problems resulting from an inability to read words from the speaker's lip movement, while 44.1% experienced problems due to the distortion of speech sounds by masks and/or visors [2].

Each type of face mask causes a low-pass filter effect, attenuating the mid-level frequencies (within the range of 500 Hz–2 kHz) of the speakers' voice, with a decibel reduction ranging from 3 dB to 4 dB or 12 dB for the N95 mask [3]. In natural acoustic conditions, the outer ear (the auricle and the external ear canal) enhances sound perception due to its shape and position [4]. The outer ear acts as a filter for reducing low frequencies, as a resonator for magnifying mid-level frequencies (within ranges of 2 to 7 kHz), and as an amplifier for high frequencies, improving spatial perception of sounds [5]. Therefore, physical distortion of the outer ear (i.e., the change of the position and shape caused by masks and visors hung over the ears) may alter the subjective perception of sound and may impair speech understanding.

Accordingly, we attempted to assess the hearing ability of individuals with and without protective masks placed behind the auricles. The research question was whether wearing a facial mask affects speech understanding and the perception of surrounding sounds (e.g., information from the radio, announcements, and warnings, etc.), and if so, to what extent the pressure on the ear affects the understanding of speech in noisy environments.

The aim of our study was to measure the extent to which the pressure of protective masks on the auriculae and external ear canal affects speech comprehension.

MATERIALS AND METHODS

The study conditions were designed to simulate real acoustic situations: speech sounds from an unchanged external source with accompanying ambient noise (e.g., as in shops, hospitals, train stations, etc.). In order to assess the ability to hear and understand speech, we carried out speech-in-noise audiometry (SIN) with a phonetically balanced monosyllabic word list in Polish. The test conditions were standardized and included a standard audiometer (AC40 Interacoustics) in a soundproof booth. The words were
Appropriate consent was obtained from the Local (University) Bioethical Commission.

RESULTS

Session 1 – test in noise without a mask

The maximum WRS values for the entire study group (N = 50 subjects) ranged from 75% to 100% (mean: 94.50%, median: 100.00%). The results were achieved at sound intensities of 50–85 dB (mean: 75.30 dB, median: 80.00 dB). In the study group, 52% of respondents (n = 26) achieved a WRS of 100%. The results were obtained for the minimum sound levels of 75.00 dB on average (min.: 60 dB, max.: 85 dB). The remainder of the group, 48% of the subjects (n = 24), achieved a WRS averaging 88.54% (median: 90.00%, min.: 75%, max.: 95%) at sound intensities of 75.63 dB on average (median: 80.00 dB, min.: 50 dB, max.: 85 dB).

Session 2 – test in noise with a mask

The highest WRS for the whole study group (n = 50) ranged from 80% to 100% (mean: 92.70%, median: 92.50%). The results were achieved at sound intensities that ranged from 55 dB to 90 dB (mean: 73.40 dB, median: 72.50 dB). In the study group, 32% of individuals (n = 16) achieved a WRS of 100% at sound intensities averaging 76.25 dB (median: 77.50 dB, min.: 60 dB, max.: 90 dB). In the remainder of the study group (68% [n = 34]), the WRS reached a mean value of 89.26% (median: 90.00%, min.: 80%, max.: 95%) at sound intensities of 72.06 dB on average (median: 70.00 dB, min.: 55 dB, max.: 85 dB).

Comparison of the findings from Session 1 and Session 2

Deterioration of speech understanding due the use of a face mask in identical acoustic conditions was demonstrated in 38% of the studied patients (n = 19) with absolute values of the word recognition score 8.95% lower (range: 5% to 20%). No changes in WRS scores regardless of the test conditions (with and without a mask) presented through a loudspeaker placed 1 m from the patients’ face, with a sound-to-noise ratio of 5 dB (+5 dB SNR). Auditory perception was assessed in two setups: Session 1 was a test conducted without a protective mask (i.e., without pressure on the auricles); Session 2 was a test conducted while wearing a protective mask behind the auricles. To equalize the study conditions, all participants were given the same type of FFP2 protective mask. All tests were performed during a single visit for each patient, one session followed by another with shuffled, verified word lists.

The study cohort included 50 healthy adult patients (N = 50), with no history of ear disease or hearing loss. A total of 36 women and 14 men aged 24–67 (mean: 45.68, median: 46.00) were included in the study. The WRS was 100% at sound volumes of 50 dB to 80 dB (mean: 58.40 dB; median: 60.00 dB). Two parameters were measured: 1) the WRS, or the maximum ratio of correctly recognized words in speech audiometry to all possible answers in the test, expressed as a percentage, and 2) the sound volume at the maximal word recognition score or the minimal value in decibels for which the subject achieved the maximum percentage of correctly identified words in speech audiometry.

In planning this study, careful consideration was given to calculating the sample size. Since this is a pilot study, we aimed for a modest statistical power of 70%, with an alpha level of 0.05 to reduce the probability of type I errors. We made two main hypotheses about the outcomes of the study. Firstly, we estimated the impact of wearing face masks on hearing audiometry, expecting a change from a baseline value of 70 dB to 75 dB. Secondly, we wanted to assess the change in word recognition and predicted a decline from an initial rate of 90% down to 70%. A power analysis indicated that a sample size of 49 participants would be sufficient to detect these changes.

Statistical analysis was performed using Statistica 13.3, with basic analysis of the variables obtained and their distribution. Next, we carried out non-parametric paired samples Wilcoxon tests in order to look for significant differences between the results of individual speech audiometry measurements. A p-value of 0.05 was adopted to interpret the results.
were found in 42% of the respondents (n = 21), whereas improvement was demonstrated in 20% of them (n = 10). The change in the absolute value of WRS increased by an average of 8% in the range of 5% to 20%. For the whole group, the mean difference in the WRS depending on the test conditions was 1.8% (p = 0.09).

For 24% of the subjects (n = 12), an increase in the sound volume ranging from 5 dB to 20 dB (10.42 dB mean) was necessary to achieve the maximum WRS. On the other hand, for 38% of the participants (n = 19), a decrease in the sound volume was necessary to achieve the maximum WRS. The reduction of the sound intensity ranged from min. 5 dB to max. 30 dB, with a mean of 11.58 dB. The remaining 38% of the subjects (n = 19) did not need to change the sound intensity to obtain the maximal word recognition score. The mean difference between the measurements in the whole study group was 1.9 dB (p = 0.22) (Fig. 1.).

**DISCUSSION**

The study was designed to investigate the impact on speech perception of masks that are worn behind the ears. Wearing masks with ear loops may distort, shift, or deflect the ears and may change the shape and size of the external auditory canal, thus leading to acoustic changes in the outer ear and hypothetically affecting auditory perception (Fig. 2.) [6–10].

A study by Wiener and Ross which assessed the amplification of sounds in the external ear canal from a source outside the ear showed an increase in sound intensity in the ear canal itself from 10 dB to 15 dB for frequencies between 2 kHz and 4 kHz, with a maximum increase in intensity between 17 dB and 22 dB for frequencies of 3 kHz [11]. Similarly, Shaw and Teranishi conducted a study on the structural relationship of the external auditory canal and the increase in the intensity of sound passing through it [4, 12–14]. Research findings showed that for frequencies between 1 kHz and 3 kHz, the only element that amplifies the sound was the external auditory canal, which amplifies sound by up to 20 dB. Thus, pressure on the external ear canal may affect speech comprehension.

The tests we used in our study – speech-in-noise audiometry and calculation of the WRS – helped us assess the ability of a person’s auditory system to identify speech stimuli. The analysis showed that when wearing a mask, the WRS decreased in 38% of the respondents by an average of 8.95%. Under the same conditions, in 62% of the subjects, the WRS did not change or increased slightly (by 8% on average). However, statistical analysis showed that these differences were not statistically significant in the study cohort. The findings were similar for the sound intensity at which the participants reached maximum WRS values during the test. When wearing the mask behind the auricles, 24% of the subjects (an increase by 10.42 dB on average) needed increased sound intensity in order to achieve the maximum WRS; 38% of the subjects did not need the sound intensity to be increased for them to obtain the maximum WRS when wearing a mask; in another 38% of the subjects, the recorded sound intensity values were lower by 11.58 dB. The differences in the maximum values of sound intensity (as in the case of the WRS) were not statistically significant (p = 0.22).

Notably, a group improved after the mask was removed, both in terms of word recognition scores and the minimum sound volume necessary to achieve the maximum recognition values (WRS). Although the statistical values do not indicate that the changes were significant, the differences may be related to changes in the position of the auricle caused by mask compression, and these may vary between individuals, depending on tissue resistance and habits/individual preferences for mask tightness. The concha serves to maintain high eardrum pressure over a broad band of frequencies and acts as a reservoir of acoustic energy [13]; therefore, changing the angle of the auricle can lead to better sound selection and a more efficient selection of words from background noise, thus improving overall speech understanding [15]. Nevertheless, our research and calculations show that simply wearing a mask behind the auricles does not affect speech comprehension.

It has to be stressed that only auditory perception was tested in this study. The simulated conditions did not take into account the aspect of lip reading or sound attenuation caused by face masks. Furthermore, the study was conducted on a homogeneous group of normally hearing adults, with an average age of 46 years. The adults adopted their speech perception apparatus to an environment with altered availability based on multimodal cues, which younger adults do even more efficiently [16]. Any hearing disorder can worsen with age and they are sometimes underdiagnosed, so one needs to remember that “universal masking and social distancing may unmask significant hearing loss-related issues that previously had been diminished or ignored” [17]. The need to use protective masks in the COVID-19 era is an element of pandemic mitigation, but the effects associated with the change in acoustics may affect the comfort and quality of life, leading to other health problems that are not directly related to the pandemic [18].

**CONCLUSIONS**

It is often reported that face masks increase listening effort for difficult noise cues. Universal mask use degrades speech quality and removes visual cues (e.g., lip reading or facial expression), but masks worn on the face which do not occlude the ears and put pressure on the auriculae do not change speech recognition performance. This may indicate a stronger role of the psycho-sociological aspects of hearing difficulties during the COVID-19
Our study and calculations show that simply wearing a mask with ear loops does not affect speech comprehension. This may indicate a stronger role of the psycho-sociological aspects of hearing difficulties during the COVID-19 pandemic with restrictions such as the widespread use of face masks.

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REFERENCES

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