Research Article

Investigating the Effects of Face Mask on Word Recognition Score Test During the COVID-19 Outbreak: Considerations and Limitations

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ABSTRACT

Introduction: Using personal protective equipment, especially face masks, in the COVID-19 pandemic era may make verbal communication difficult. Furthermore, acoustic changes in mask-wearing conditions may affect speech audiometry results. This study investigates the effect of wearing a face mask on the word recognition score and the role of speech frequency content in this effect.

Materials and Methods: This study was planned and conducted in two phases. In the first phase, the validity and reliability of two speech material lists, high-pitch and low-pitch, were determined. In the second phase, the word recognition score was measured for "mask-wearing" and "covering mouth without a mask."

Results: The statistical analysis showed that the content validity ratio was 0.92, and the content validity index was 0.8. Therefore, both speech lists were valid. For these lists, the mixed analysis of variance analysis showed that the scores for "mask-wearing" were significantly lower than "covering mouth without a mask," and there was more reduction in scores for the high-pitched list ($F=8.7$, $df=1$, $P<0.005$).

Conclusion: In terms of the impact of a face mask on speech, explaining how speech audiometry is performed, especially in monitoring treatments, may help limit the probability of misinterpretation of speech test findings. Furthermore, understanding the impact of face masks on word recognition scores in adopting sufficient auditory rehabilitation procedures is necessary.

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Introduction

From the onset of the COVID-19 pandemic, all scientists agreed that using personal protective equipment (PPE) in general and a face mask in specific conditions can disrupt the chain of infection; however, using a face mask could make challenges for verbal communication as the dominant medium of communication [1-4]. Face masks can render visual cues, gestures, and facial expressions invisible for speech perception. Consequently, verbal communication might become complicated and limited [3, 5]. Previous research on wearing a face mask during the COVID-19 pandemic found that it reduced speech-in-noise scores [3, 6-8]. This was confirmed by a questionnaire study aiming to collect people's attitudes on the effects of face masks on communication [9]. Regardless of the significant effect of face masks on reducing visual information necessary for audiovisual perception, spectral changes in acoustic signals were considered in various face masks [10, 11]. Lower sound pressure levels (SPL) and reduced speech intelligibility with a face mask on were reported in the published studies [1, 3, 4, 12]. Specifically, surgical masks and N95 respirators can lower the SPL between 3 to 12 dB in the high-frequency region [13]. Another study found an 8-dB SPL reduction in frequencies above 1 kHz but none below [14]. As a result of the face mask, decreased SPL in the high-frequency range is predicted, which is essential for speech intelligibility. It is anticipated to impact communication in common circumstances, such as the workplace and education [13, 15, 16]. Besides, the aforementioned acoustic changes in mask-wearing conditions could change the results of audiological assessments. Therefore, speech recognition measures might be influenced by using a face mask. This possibility is essential since these assessments are used to describe the extent of hearing impairment in terms of how it affects speech understanding, make the differentiation between sensory and neural hearing impairments [17-19], and determine the necessity and type of amplification, other audiologic rehabilitation [20, 21], verifying their benefits [17] and for monitoring patient performance over time for either diagnostic or rehabilitative purposes. Although these tests should be done with standardized recorded speech materials, these assessments are usually performed live by many audiologists worldwide [20]. Accordingly, this question arises whether the obtained word recognition score (WRS), which is performed using a face mask due to the special conditions of the COVID-19 pandemic, will be affected by this acoustic damping and also using live sound with a face mask can still be a valid and reliable test.

This study investigates the effect of wearing a face mask on WRS and determines the role of speech frequency content on this effect. The first part of the study determines the validity and reliability of two lists of speech materials for WRS. One list (low pitch list) was dominated by lower frequency monosyllabic words than the other list (high pitch list). In the second part, WRS for two lists in "mask-wearing" and "covering mouth without a mask" were evaluated and compared to reveal the effects of acoustic changes in terms of face masks in live testing.

Materials and Methods

This research was designed and carried out in two phases. The validity and reliability of the two speech material lists, namely "high-pitch" and "low-pitch," were determined in the first phase. WRS was measured in the second phase under "mask-wearing" and "covering mouth without mask."

First phase: Validity and reliability

The "low-pitch" list consisted of 50 words with the dominance of consonants whose frequency spectrum had higher energy below 1 KHz, and the "high-pitch" with the same number of words with consonants with a higher energy of the frequency spectrum above 2 KHz. Both lists were utilized to measure WRS under the two conditions indicated above. Both lists included meaningful monosyllabic words in the consonant-vowel-consonant structure. The lists were also phonetically balanced. Furthermore, all words were minimal pairs. Accordingly, there were similar words in the two lists whose difference was in one phoneme. For example, if there was a word like "/dir/" in the "low-pitch" list, there was a word with the same tonality like "/zir/" in the "high-pitch" list. To validate the lists, ten experts (6 speech and language pathologists, two linguists, and two audiologists) were asked to describe each word of the lists as "necessary," "suitable but not necessary," or "not necessary." The content validity ratio (CVR) was calculated for the responses given by the professionals. Moreover, the content validity index (CVI) was calculated after it was asked by the professionals to describe each word of the list based on a 4-point Likert scale from "relevancy," "simplicity," and "clarity" points of view. The Likert scale options were "not relevant," "somehow relevant," "relevant," and "very relevant." After finalizing the words, they were distributed in 6 lists to minimize the effect of memory and learning in WRS tests. All subjects were evaluated in two-week intervals to ensure the reliability.

Figure 1. Test conditions: Mask-wearing and covering mouth without mask

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Second phase: Word recognition score tests

In this study, 30 adolescents, an equal number of each gender, participated in this phase (mean=28.33±5.15 years). They all had normal hearing [17], were right-handed, and monolingual. None of them reported any history of ear surgery or disease, ototoxicity, head trauma, or neurologic problems. The experiment was administered according to the ethical guidelines of Iran University of Medical Sciences. All participants filled out the consent form. Then, demographic and medical questionnaires were filled, and the otoscopic assessment and pure tone and speech audiometry were administered with a GSI-61 clinical audiometer (Grason–Stadler, Eden Prairie, MN); meanwhile, admittance testing was done with Zodiac 901 (Madsen co, USA).

The participants were tested for WRS in "mask-wearing" and "covering mouth without a mask." The latter is the conventional method of WRS testing in many audiology clinics (Figure 1). This study used a surgical mask, and the tests were done at 30 dB SL in an acoustic booth presented through supraural TDH39. The test lists were selected randomly and were uttered by a female experimenter. The examiner controlled the voice by view meter, and the manner of presentation was kept as constant as possible. The sequence in which the circumstances were tested was also randomized. Each participant's ratings under various situations were collected and evaluated using the SPSS software, version 21. The significance level was set at 0.05.

Statistical analysis

For the validity assessment, CVI and CVR were determined for the lists. The Cronbach α was calculated to test the reliability of the lists. The two-way repeated measure analysis of variance was used to test the effects of conditions and lists, and the Tukey post hoc testing was used for further analysis.

Table 1. Mean±SD for different conditions and lists

Condition	List	Mean±SD	Participants (n)
WRS with covering mouth without a mask	Low pitch	96.6667±3.33563	30
	High pitch	94.1333±4.66634	30
	Total	95.4000±4.21941	60
WRS with mask-wearing	Low pitch	91.8667±4.98088	30
	High pitch	86.6667±4.96424	30
	Total	89.2667±5.58408	60

WRS: Word recognition score.

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Results

CVR should be above 0.62 for the setting where ten experts assess a scale [22] in the current study. The rates for CVR and CVI were 0.92 and 0.8, respectively. Therefore, the speech lists were valid, and there was a unanimous agreement for them among experts.

For the reliability test, the values of the Cronbach α for the two conditions were above 0.9, meaning that the speech lists were highly reliable and suitable for use in WRS testing.

The Mean±SD for different factors are provided in Table 1. Since there was a between-group factor (low- and high-pitch lists) and a within-group factor (the condition), the mixed analysis of variance test was used to compare the means of the scores of WRS. The results are shown in Table 2. For both lists, the scores for "mask-wearing" were significantly lower than for the "covering mouth without mask" condition; however, there was more reduction in scores for the high-pitched list (F=8.7; df=1; P<0.005). The effect size for the high-pitch list (d'=1.5) was larger than for the low-pitch list (d'=1). The data is provided in Figure 2.

Discussion

This study aimed to assess the effects of face masks on WRS testing. The result showed that wearing a face mask affects word recognition, especially for consonants with high-frequency dominance. The mean scores of "mask-wearing" and "covering mouth without mask" in the present study showed a 6% difference, which is in line with what was reported by Bandaru et al. [6]. In recent studies, the effects of wearing face mask on

Table 2. Mixed analysis of variance results

Factor	df	F	P
Condition*	1	184.8	0.000
List**	1	12.78	0.001
Condition list***	1	8.73	0.005

*Mask-wearing and covering mouth without mask, **Low-pitch and high-pitch, ***Interaction between condition and list.

Notes: The significance level was set at 0.05.

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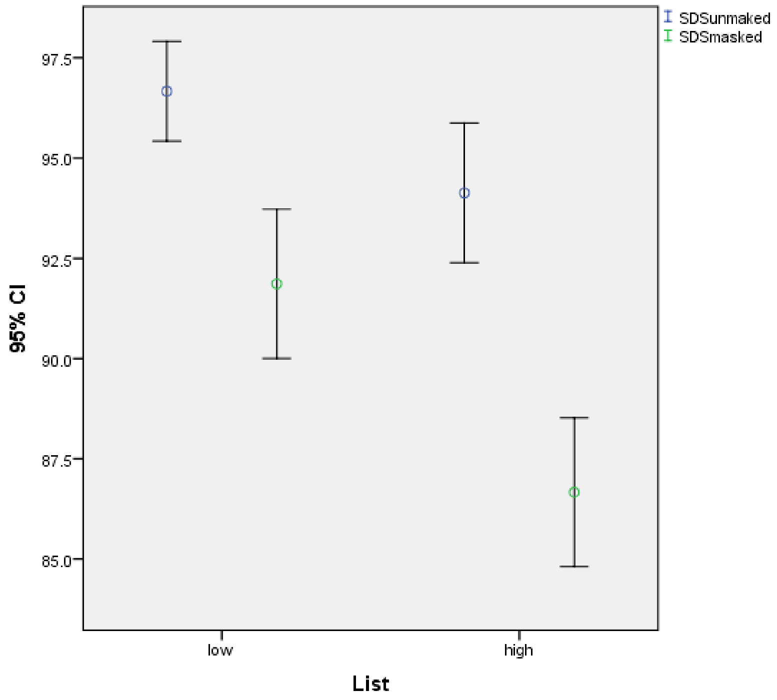

Figure 2. Mean and 95% CI for different conditions and lists

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voice parameters and communication were well-studied. Saeidi et al. [23] classified the effects of face masks on recorded speech into two categories: Active effects (change in speaking effort or manner) and passive effects (filtering effect due to the form and materials of the face mask). The effects of face masks on various characteristics of live voice are also reported in previous studies, including increased vocal effort and fatigue, vocal tract discomfort, intensity, harmonics-to-noise ratio, spectral values at high frequencies, and change of formants [10]. Because the level of the examiner's voice and how words were uttered during the test were the same in the current investigation, the variations observed in the study might be attributed to the passive effect of wearing masks. The main passive effect among studies was induced filtering regarding wearing face masks. Acoustic analysis of speech signal [24, 25] or speech recognition threshold evaluation [6], following face mask usage, showed decreased sound pressure levels in the range from 3 to 27 dB SPL [13, 16]. Therefore, face mask usage as an effective factor in understanding speech signals has been considered. In addition, the greater impact of face masks on the high-frequency part of the speech signal, despite the difference in the range [13, 4] and the high importance of this part of the signal in word recognition and speech comprehension, is noteworthy. Hence, the received signal when the speaker is wearing a face mask is reported to be equivalent to slight high-frequency hearing loss [13]. The frequency content of designed lists (low pitch <1, high pitch >2), the difference in the effect of high-frequency consonants list, the greater effect of face mask on high frequencies, and the effect of filtering on word comprehension are suggested. This is in line with previous studies [4, 13]. The confusion matrix showed that the most frequent consonants that were mistaken were /s/, /sh/, /f/, and /v/. Since these consonants had high-frequency energy, the problem for these consonants was expected; however, the significant difference reported for the low-pitch list between the two test conditions could be attributed to the overall decrease in the intensity level caused by wearing a face mask. In both evaluation modes, the intensity level of 30 dB SL was used to reduce the variability of test conditions. As a result, this research could not evaluate the influence of each element, and a study should be conducted with and without a face mask at the most comfortable level. However, the considerable difference in face mask effects on WRS with high-frequency consonants list vs low-frequency consonants list implies that raising the intensity level is insufficient to compensate for face mask-induced high-frequency filtering. WRS is an important part of routine audiology battery tests, used in differential diagnosis, following up hearing status in the treatment process, especially in cases with sudden hearing loss, and determining the prognosis of hearing assistive devices usage. Significant differences in test results while visual cues are eliminated in both test conditions and who recognizes words only by auditory information, in line with studies that have considered face mask filtration in addition to its reducing effect on visual cues [3, 4, 16]. Although all word recognition scores were in the normal range [17] according to clinical diagnostic criteria, a 6% difference might seem trivial. It should be noted that the test was performed using a three-layer surgical mask in young, normal-hearing adults in quiet. Hence, the possibility of worsening results by changing these conditions exists. Furthermore, among the many forms of PPE [13], surgical face masks had the least amount of decrease in intensity levels (as low as 3 to 7 dB SPL), and this amount was in the event of employing just one surgical face mask [13]. While many audiologists employ masks or shields to maximize the sound-dampening effect, many utilize face masks with higher defensive power. Therefore, this difference might vary from one clinic to another in terms of different types of PPE usage or, based on experience, performing the test without a face mask, and it is quite dramatic, especially when the test is performed to monitor the effect of treatment or rehabilitation, and can mistakenly disrupt the treatment process. Where it is impossible to perform a test without a face mask, mentioning the conditions under which the test was performed is somewhat helpful in avoiding this misinterpretation. According to the results of the present study, the importance of the cross-check principle to avoid misdiagnosis and interpretation is raised. Authors recommend the assessments of possible impacts of face masks on speech recognition in people with different degrees of sensory-neural hearing loss and elderly population and auditory rehabilitation interventions.

Conclusion

Using recorded materials has already been recommended to eliminate interference in performing tests and achieving valid results. Since lists of standard, recorded words are available in many languages. Its implementation does not depend on equipment or complex skills; it is the best option in the current situation to maintain the health of audiologists and clients, along with accurate and valid evaluation. Regarding live speech materials used for maintaining health, the cost-benefit type of personal protective equipment is recommended according to the degree of effectiveness mentioned in the studies. Previous studies showed that surgical masks with the least filtering impact are preferable. Mentioning how the test is conducted, particularly while monitoring treatments, may help lessen the possibility of misinterpreting speech test findings. Additionally, being aware of the effects of face masks on counseling, prescribing, and adjusting hearing aids can lead to better decisions in this area. It is necessary to consider that the difference among word recognition scores is obtained in normal-hearing adults with one surgical mask and quiet. However, audiologists use face masks with different materials, more than one face mask, or a combination of mask and shield in clinical settings, which can intensify the abovementioned effects. This intensifies the difference observed in the present study based on studies. Consequently, in clinical settings, obtaining word recognition scores is advised to monitor outcomes in various sessions under the same circumstances, and the method for obtaining word recognition scores should be mentioned in the audiogram sheet. Considering this finding while giving advice, prescribing, and modifying hearing aids might also help make better judgments. Since the results of this study indicated that high-frequency words are more affected by wearing a mask, it is suggested that audiologists consider both high-frequency and low-frequency words equally when evaluating the patients, especially in mask-wearing conditions. This is because wearing a mask on high frequencies does not affect the overall results of the test.

Ethical Considerations

Compliance with ethical guidelines

The Research Ethics Committee of Iran University of Medical Sciences (IUMS) approved this study for conducting medical research in Iran (Code: IR.IUMS.REC.1401.225).

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Authors' contributions

Conceptualization, resources and investigation: Azadeh Borna, Seyede Zohre Mousavi and Mehri Maleki; Supervision: Mohammad Maarefvand; Methodology, funding acquisition and writing: All authors.

Conflict of interest

The authors declared no conflict of interest.

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