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Comparison of speech recognition performance with and without a face mask between a basic and a premium hearing aid in hearing-impaired listeners

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A R T I C L E I N F O

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COVID-19

A B S T R A C T

Background: The mask mandate during the COVID-19 pandemic leads to communication challenges as sound energy gets reduced and the visual cues are lost due to the face mask. This study examines the impact of a face mask on sound energy and compares speech recognition performance between a basic and a premium hearing aid.
Methods: Participants watched four video clips (a female and a male speaker with and without a face mask) and repeated the target sentences in various test conditions. Real-ear measurement was performed to investigate the changes in sound energy in no mask, surgical, and N95 mask conditions.
Results: With the face mask on, sound energy significantly decreased for all types of masks. For speech recognition, the premium hearing aid showed significant improvement in the mask condition.
Conclusion: The findings emphasize and encourage health care professionals to actively use communication strategies, such as speaking slowly and reducing background noise, when interacting with individuals with hearing loss.

1. Introduction

Hearing loss (HL) can have various symptoms and causes [1,2]. It could be caused by diseases in the ear (i.e., ear infection) and accompanied by tinnitus. It is reported in numerous studies that HL negatively affects quality of life [3–5]. There are multiple ways to compensate HL, but typically, the first step of hearing rehabilitation starts with hearing devices, such as hearing aids (HAs) [1,6]. A HA is a hearing device that aids individuals in hearing by amplifying sounds. The device is selected and optimized based on several factors including audiometric thresholds, family support, lifestyle, and communication needs [7]. HAs will enhance sound, but as both auditory and visual cues play a role in communication [8–14], it is still crucial for individuals to utilize communication strategies, such as speaking slowly and reducing background noise [15].

With the COVID-19 pandemic, due to the mask mandate, communication has become more challenging for individuals with HL [16,17]. Face masks are reported to attenuate mid-to-high frequency and individuals lose access to visual cues [18–22]. Nguyen et al. (2021) examined voice characteristics of 16 adults with and without a surgical and a KN95 mask. The participants recorded the vowel /a/, phrases in the Consensus Auditory-Perceptual Evaluation of Voice, and the Rainbow passage. Mean spectral levels in low (0–1000 Hz) and high (1–8000 Hz) frequency ranges were analyzed. While no significant effects were observed for the low frequency range, the spectral levels were reduced by 5.2 dB with the KN95 mask and by 2.0 dB with the surgical mask [20]. In 2020, Goldin and colleagues investigated the impact of various medical masks on speech signals. Using a head and torso simulator, the amount of sound attenuation was measured in four different conditions: no mask, simple mask, N95 mask 1 and N95 mask 2 [19]. Again, the N95 mask showed the most amount of sound attenuation (12 dB). The level of speech signals was decreased by 3 to 4 dB with

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the simple mask [19]. Brown et al. (2021) recruited 360 young and older adults to investigate the impact of face masks on speech intelligibility. The authors presented 150 sentences in which each sentence had four key words in no mask, surgical mask, black cloth mask with and without a paper filter, and cloth mask with a transparent mask. In the presence of noise, the participants' speech intelligibility significantly decreased with all types of masks [23]. Salamah et al. (2022) conducted a cross-sectional survey for 80 individuals and asked about hearing aids and communication with a face mask during the pandemic. The results showed that 40 % of the respondents reported that understanding speech is harder due to the face mask. 41.3 % of the respondents also mentioned that speech understanding is harder because they are unable to see the lip movements [16].

There are several literatures exploring communication difficulties and quality of life of individuals with HL and the benefit of hearing devices [16,17,24,25]. However, the comparison of performance between a basic and a premium hearing aid on speech performance has not been investigated yet. This study explores acoustic characteristics of a basic and a premium HA and compares their speech recognition performance in hearing-impaired listeners.

2. Material and methods

2.1. Participants

Thirty native Korean speakers with HL were enrolled in the study. The age range of the participants was from 24 to 69 years old with the mean age of 57.0 years (SD = 12.2). All participants had sensorineural HL with an asymmetry in hearing thresholds below 10 dB across testing frequencies (250, 500, 1000, 2000, 4000, and 8000 Hz) in both ears. The puretone averages were 50.4 dB in the right ear and 51.1 dB in the left ear. The average word recognition scores were 78 % in both ears. Individuals who were unable to watch TV at a distance of 1 m and those with otological pathology and neurological and mental disorders were excluded from the study. All experimental procedures were approved by Samsung Medical Center Institutional Review Board. Prior to testing, an informed consent document was obtained from the participants.

2.2. Puretone audiometry

Pure-tone audiometry was performed in a sound booth using insert earphones and an AudioStar Pro (Grason-Stadler, USA) audiometer.

2.3. Video recordings

Four video recordings were used in the study: a female speaker with and without a face mask and a male speaker with and without a face mask. A KF94 (‘Korea Filter with 94% filtration efficiency’) mask which is reported to be equivalent to N95 and FFP2 masks [26,27] was used for this study. The speakers recorded test sentences from the Korean Standard Sentences Lists for Adults (KSSL-A) which is a speech test widely used in Korea. The recordings were edited to have the female and male speakers alternating. The commercial editing tools from Adobe Systems, USA (Adobe Premiere Pro and Adobe Audition) were used.

2.4. Real-ear measurement

Following the instructions from the manufacturer [28], real-ear measurement (REM) in live mode was completed using Aurical Freefit (Natus Medical Inc., Denmark) to examine the sound pressure level (SPL) changes of sound stimuli. The testing was performed in three conditions: no mask, surgical mask, and N95 mask. Audio recordings of the KSSL-A list 1 for both speakers were used.

2.5. Speech recognition testing

The speech testing was conducted using the video recordings in a semi-anechoic chamber. Four conditions were used: no mask & no visual cues, no mask & visual cues, mask & no visual cues, and mask & visual cues. A basic (Oticon Siya 2) and a premium (Oticon More ONE) HA was used for performance comparison with additional features (i.e., noise reduction) off. The functionality of the HAs was also checked through electroacoustic testing. Wearing each set of the HAs, the participants sat on a chair located 1 m away from the loudspeaker, listened to the test sentences, and repeated them back to the tester. With the target sentences presented at 50 dBA, percent-correct scores were obtained. The testing took an hour and breaks were given as requested.

2.6. Statistical analysis

Statistical analysis was performed using SPSS version 26 (IBM Corporation, USA). As our results did not pass normality test, the Wilcoxon-signed rank test was performed. Differences in SPLs as well as speech recognition performance in test conditions were analyzed.

3. Results

3.1. The impact of face mask on sound pressure level

Fig. 1 illustrates the SPLs for both speakers. The mean SPLs were 31.6-, 28.9-, and 28.5-dB for the no mask, surgical, and N95 conditions, respectively for the female speaker. SPL differences between the conditions were 2.8 dB SPL (no mask – surgical) and 3.1 dB SPL (no mask – N95). For the male speaker, the mean SPL for the no mask condition was 28.9 dB. The mean SPLs for the surgical and N95 masks were 27.9- and 24.5-, respectively. SPL differences between the conditions were 0.9 dB (no mask – surgical) and 4.4 dB (no mask – N95). For both speakers, statistical significance was observed between no mask and surgical ($P < 0.001$) and between no mask and N95 conditions ($P < 0.001$). Comparing the no mask and the surgical mask condition, the maximum sound attenuation occurred at 2000 Hz (5.1 dB). Comparing the no mask and the N95 mask condition, the maximum sound attenuation was observed at 4000 Hz (6.2 dB). For the male speaker, for both conditions (no mask – surgical and no mask – N95), the SPLs decreased the most at 1000 Hz (2.5 dB for no mask – surgical and 7.0 dB for no mask – N95).

3.2. Performance comparison with and without visual cues

Table 1 describes performance differences between the basic and premium HAs. While the two devices did not show any statistical significance for speech recognition performance in the no mask condition regardless of the presence of the visual cues, they showed statistical significance when the speakers were wearing a mask ($P = 0.014$ for the no visual cues condition and $P = 0.021$ for the visual cues condition).

3.3. Speech recognition performance with and without a face mask

When the visual cues are available, both the basic and premium HA showed statistical significance on speech recognition in the no mask and mask conditions ($P < 0.001$ for both conditions). However, when the visual cues are unavailable, no statistical significance on speech recognition was observed in the no mask and mask conditions ($p = 0.201$ for the basic HA and $p = 0.958$ for the premium HA).

4. Discussion

This study investigates the impact of face mask on SPLs and compares speech recognition performance between the basic and the premium HA. Our findings showed that when the speakers were wearing a face mask, individuals' speech recognition performance statistically

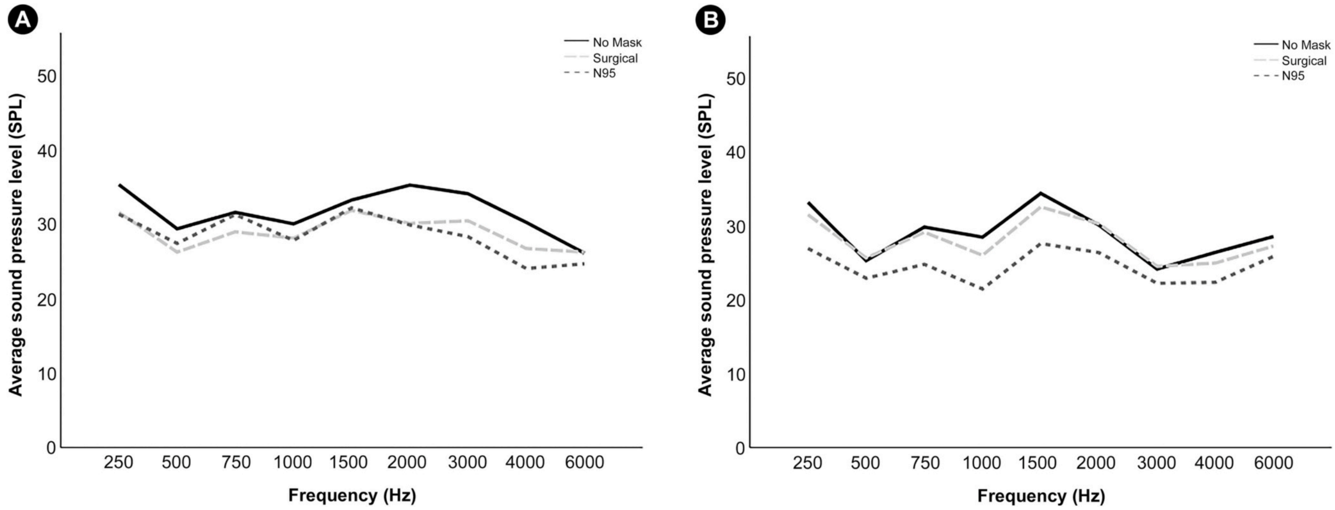

Fig. 1. REM results of female (A) and male (B) speakers.

Table 1
Statistical analysis of the HAs' speech recognition performance in the no visual cues and visual cues conditions (*$P < 0.05$).

Mask	Visual cues	HAs (Inter quartile range)		P
		Basic	Premium	
No mask	No visual cues	10 (0–40)	20 (0–50)	0.108
	Visual cues	60 (20–90)	70 (57.5–82.5)	0.071
Mask	No visual cues	5 (0–25)	20 (0–40)	0.014*
	Visual cues	10 (0–32.5)	25 (7.5–50)	0.021*

improved with the premium HA in both no visual cues and visual cues condition. Although the two HAs did not show any significance performance differences in the no visual cues condition, when the visual cues were available, the premium HA showed statistically significant speech recognition performance even if the speaker was wearing a face mask. Similar to pre-existing studies [8,10,11,14,29,30], significant improvement in speech recognition performance indicates that visual cues are helpful for communication. The authors believe that the premium HA showed better performance as it generally has more channels for signal processing and faster processing speed than the basic HA. Channel refers to different areas or groups of frequencies that HAs will process. If HAs have two channels, it means that the HAs will break the frequencies into two different ranges for processing. If HAs have 10 channels, the HAs will break the frequencies into ten different ranges for sound processing, allowing more specific adjustments or programming. The REM results also demonstrated significant reduction in SPLs with face masks. For both speakers, the lowest mean SPLs were observed with the N95 mask. The maximum attenuation of sound was observed at 2000- (no mask – surgical) and 4000 Hz (no mask – N95) for the female speaker and at 1000 Hz (no mask – surgical and no mask – N95) for the male speaker. Findings of this study are in line with previous studies that speech frequencies, which are frequencies that are critical for speech understanding, are affected by face masks [19,31,32].

In sum, these findings heighten the importance of the active use of communication strategies. Regardless of the pandemic, communication difficulty arises when visual information, such as lip movements and facial expressions, are unavailable. On a personal level, this communication difficulty can affect one-on-one conversations. On a professional level, communication difficulty could lead to poor interactions between healthcare professionals and patients and quality of care [33–40]. Kwame and Petrucka (2021) conducted a study to identify barriers and facilitators of patient-centered care and communication. The authors reported that poor communication between healthcare professionals and patients could affect outcomes and perceptions of the quality of care [40]. Environment factors included noisy surroundings and lighting. These days, most countries are no longer enforcing the mask mandate. Even if the preventative measures are dropped for COVID-19, it is essential to keep in mind that other respiratory diseases could arise in the future, so healthcare professionals are strongly encouraged to remind themselves about communication strategies and use them when interacting with individuals with HL.

Future studies with a larger sample size as well as various listening conditions are necessary. Including a noise condition could reflect the real-world listening environment. Recruiting participants with different characteristics of HL would allow us to compare the performance between the HAs at a more specific level.

5. Conclusions

The findings of the study showed that when the speakers were wearing a face mask, individuals' speech recognition performance statistically improved with the premium HA, emphasizing the active use of communication strategies.

Ethics approval and consent to participate

All experimental procedures were approved by Samsung Medical Center Institutional Review Board. Prior to testing, an informed consent document was obtained from the participants.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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CRediT authorship contribution statement

H·Y·S, M.J, J.G.P., H.M.B, and I.J.M conceptualized the study, M.J and H·Y conceived the experiments, J.G.P., H.M.B, and I.J.M reviewed the concept. M.J and H.Y conducted the experiments, and H.Y·S analyzed the results. H.Y·S wrote the main paper and all authors reviewed the manuscript.

Declaration of competing interest

No potential conflict of interest relevant to this article was reported.

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