The effects of face coverings and remote microphone technology

Amanda M. Rudge, Ph.D, **Valerie Sonneveldt**, Au.D, and **Betsy Moog Brooks**, Ed.D, present their findings on speech perception abilities in a classroom environment (American study)

Many schools across the nation, including those that serve individuals who are deaf or hard of hearing, are planning to open in various capacities for face-to-face lessons in the fall of 2020 or sooner. For all children, especially those who utilize cochlear implants and/or hearing aids to communicate, access to quality auditory information is critical for speech perception and learning. At present, there is a dearth of information about the impact of personal protective equipment on a listener's ability to perceive speech. There exist several options for face coverings to help slow the spread of the novel coronavirus, Covid-19, in enclosed spaces, including N95 respirators, surgical masks, cloth masks, cloth masks with clear windows, and face shields. Initial findings from leaders in hearing healthcare indicate that masks of any kind are attenuating speech sounds, with particularly diminished quality of higher frequency sounds, which largely contribute to meaning in language (Dyre, 2020; Goldin, Weinstein, & Shiman, 2020; Gordey, 2020). Additionally, preliminary evidence indicates that personal remote microphone (RM) systems can alleviate some of these diminished sound qualities when paired with face coverings (Dyre, 2020; Gordey, 2020). These systems, such as Phonak's digital Roger technology, are designed to improve the listener's access to a quality signal regardless of the distance from the talker or the environment's acoustics by having the talker wear a microphone that wirelessly transmits his/her voice to a receiver coupled to and/or integrated into the listener's hearing device. While the data available in this area are sparse, studies have been limited to clinical settings with testing occurring in close quarters of three feet or in sound-treated booths with recorded speech stimuli. There exists no data from real-life settings, such as a classroom with social distancing measures of at least six-feet separation in place.

Figure 1. Face coverings

Figure 1. Four variations of face coverings investigated both with and without remote microphone technology. These variations were selected based on commercial availability and the likelihood of use in classroom settings. Not pictured is the baseline condition (no face covering, no remote microphone).

To begin meeting the need for functional classroom outcomes, the Moog Center for Deaf Education, St. Louis, Missouri, investigated how variations of face coverings, used with and without a Phonak Roger personal remote microphone digital modulation (DM) system, affect speech perception in a classroom environment using monitored live-voice while separated with six feet between listener and speaker. The primary objective of this project was to document the differences in speech perception abilities of adults with normal hearing when listening to monitored live-voice from a speaker who was six feet away in nine various listening conditions, including four variations of face coverings with and without remote microphone technology, as well as a baseline condition of no face covering and no remote microphone. The figure below depicts the various types of face coverings used in the test conditions for this project.

a. Cloth mask
b. Windowed cloth mask
c. Fully transparent ClearMaskTM
d. Face shield

Participants in this study included 15

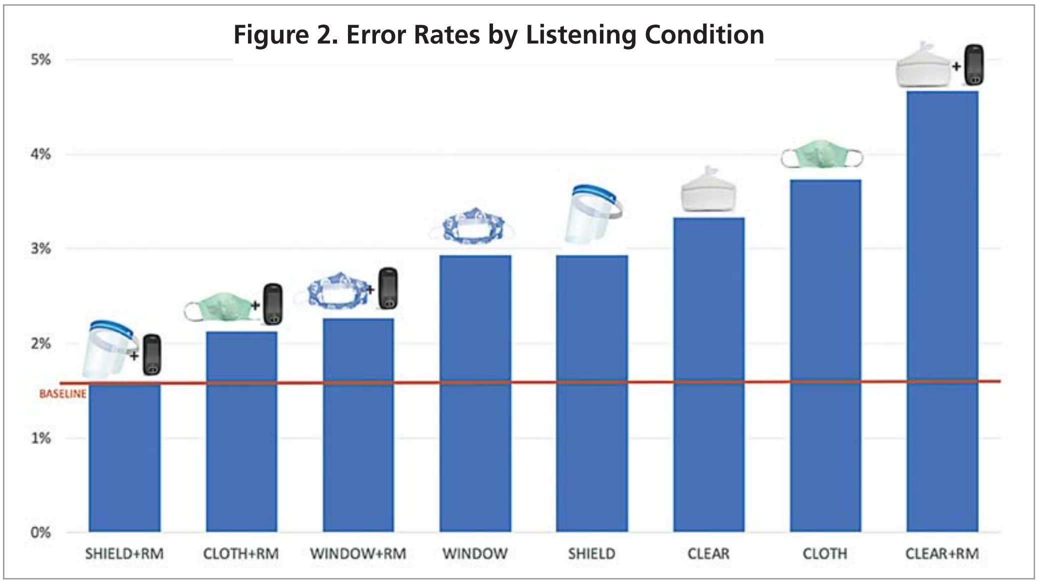

Figure 2. Percentage of speech perception error as measured by the CNC test in nine variations of face covering conditions, including the baseline condition of no face covering and no remote microphone (RM) represented by the orange horizontal reference line.

adults with hearing thresholds in the normal range (25 dB HL or better) across octave frequencies of 250 – 8000 Hz in each ear, as evaluated in a sound-treated booth at the Moog Center on the day of the speech perception testing. Speech perception assessment was conducted in an unoccupied classroom at the Moog Center using the consonant/nucleus/consonant (CNC) test (Peterson & Lehiste, 1962). This assessment contains 50 monosyllabic words (eg merge, seize, yearn, etc) that exhibit phonemic distributions proportional to the structure of CNC words, which occur with minimal frequencies of one per million in agreement with the Thorndike and Lorge frequency count (Thorndike & Lorge, 1944). The assessment was administered by a Teacher of the Deaf using monitored live-voice, seated at the CDC's recommended social distancing guideline of six feet from the participant (CDC, 2020). The same teacher presented the words for all participants and trained to maintain a vocal output of approximately 60 dB SPL, as measured by a sound pressure level meter at the listener's ear in the baseline condition (no face covering, no remote microphone). Participant responses were recorded by the speaker and scored on the number of words repeated correctly. A full and randomized word list was presented in each of the following nine listening conditions:

1. Baseline: no face covering/no remote microphone
2. Cloth mask/no remote microphone
3. Cloth mask/with remote microphone
4. Cloth mask with clear window/no remote microphone
5. Cloth mask with clear window/with remote microphone
6. Fully transparent ClearMaskTM/no remote microphone
7. Fully transparent ClearMaskTM/with remote microphone
8. Face shield/no remote microphone
9. Face shield/with remote microphone

For conditions utilizing the remote microphone (RM) system, the speaker wore a Phonak Roger Touchscreen transmitter positioned six inches below the mouth, while participants wore Phonak Roger Focus receivers set to default gain values (EasyGain = 0) at the right and left ears with open dome eartips. To evaluate the effect of the face coverings and RM system use on speech perception abilities alone, participants were instructed to close their eyes or divert their gaze from the speaker's mouth and face during all conditions, including those in which the speaker's lips were visible.

Descriptive analysis identified the mean baseline (no face covering, no RM) speech perception error rate to be under 2%. When comparing the baseline to other face covering conditions, it was discovered that the highest error rate (M = 5%) occurred when listening to a speaker who wore the ClearMask™ and RM together. The lowest error rate (M = 1.6%) occurred when listening to a speaker who wore a face shield and RM together. This error rate was nearly identical to the baseline no face covering condition. The speech perception error rates for each of the listening conditions compared to the baseline are presented in Figure 2.

To assess whether significant differences existed in speech perception error rates among listening conditions, a repeated-measures analysis of variance (ANOVA) with one within-subjects factor was conducted. The main effect for the within-subjects factor was revealed to be significant across listening conditions at the $\alpha = 0.10$ level $F(8, 134) = 1.93$, $p = .062$, indicating that there were significant differences between the listening condition values of the baseline condition of no face covering and no RM, cloth mask alone, cloth mask with RM, ClearMask™ alone, ClearMask™ with RM, windowed mask alone, windowed mask with RM, face shield alone, and face shield with RM. Table 1 presents the ANOVA results. After confirming the

Table 1. Repeated-measures ANOVA, a = .10

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Subjects	57.926	14	4.138	2.138	0.015	1.566
Groups	29.926	8	3.741	1.933	0.062	1.726
Error	216.741	112	1.935			
Total	304.593	134				

Table 2. Pairwise comparisons

Condition 1	Condition 2	mean	q-stat	p-value	Cohen d
BASELINE	CLOTH	1.00	2.78	0.04	0.72
BASELINE	CLOTH+RM	0.20	0.56	0.57	0.14
BASELINE	CLEARMASKV	0.80	2.23	0.17	0.58
BASELINE	CLEARMASK™+RM	1.47	4.08	0.02	1.05
BASELINE	WINDOW	0.60	1.67	0.19	0.43
BASELINE	WINDOW+RM	0.27	0.74	0.60	0.19
BASELINE	SHIELD	0.60	1.67	0.20	0.43
BASELINE	SHIELD+RM	0.07	0.19	0.84	0.05
CLOTH	CLOTH+RM	0.80	2.23	0.05	0.58
CLOTH	CLEARMASK™	0.20	0.56	0.79	0.14
CLOTH	CLEARMASK™+RM	0.47	1.30	0.35	0.34
CLOTH	WINDOW	0.40	1.11	0.46	0.29
CLOTH	WINDOW+RM	0.73	2.04	0.21	0.53
CLOTH	SHIELD	0.40	1.11	0.42	0.29
CLOTH	SHIELD+RM	1.07	2.97	0.03	0.77
CLOTH+RM	CLEARMASK™	0.60	1.67	0.33	0.43
CLOTH+RM	CLEARMASK™+RM	1.27	3.53	0.05	0.91
CLOTH+RM	WINDOW	0.40	1.11	0.32	0.29
CLOTH+RM	WINDOW+RM	0.07	0.19	0.83	0.05
CLOTH+RM	SHIELD	0.40	1.11	0.21	0.29
CLOTH+RM	SHIELD+RM	0.27	0.74	0.48	0.19
CLEARMASK™	CLEARMASK™+RM	0.67	1.86	0.14	0.48
CLEARMASK™	WINDOW	0.20	0.56	0.75	0.14
CLEARMASK™	WINDOW+RM	0.53	1.48	0.45	0.38
CLEARMASK™	SHIELD	0.20	0.56	0.75	0.14
CLEARMASK™	SHIELD+RM	0.87	2.41	0.07	0.62
CLEARMASK™+RM	WINDOW	0.87	2.41	0.23	0.62
CLEARMASK™+RM	WINDOW+RM	1.20	3.34	0.09	0.86
CLEARMASK™+RM	SHIELD	0.87	2.41	0.19	0.62
CLEARMASK™+RM	SHIELD+RM	1.53	4.27	0.01	1.10
WINDOW	WINDOW+RM	0.33	0.93	0.27	0.24
WINDOW	SHIELD	0.00	0.00	1.00	0.00
WINDOW	SHIELD+RM	0.67	1.86	0.07	0.48
WINDOW+RM	SHIELD	0.33	0.93	0.42	0.24
WINDOW+RM	SHIELD+RM	0.33	0.93	0.52	0.24
SHIELD	SHIELD+RM	0.67	1.86	0.05	0.48

presence of significant difference in speech perception across listening conditions through ANOVA, multiple comparison tests were administered using pairwise t-tests with Tukey's HSD procedure to determine the extent of the difference between each condition. Two of the face coverings paired with RMs were revealed to facilitate significantly better speech perception abilities than their non-RM counterpart conditions: shield alone compared to shield with RM (p = .05, Cohen d = 0.48), and cloth alone condition compared to Cloth with RM (p = .05, Cohen d = 0.58). Additionally, the two listening conditions with the highest speech perception error rates, Cloth alone and ClearMask™ with RM, also were significantly different from the baseline condition (p = .37, Cohen d = 0.72; p = .15, Cohen d = 1.05, respectively). Table 2 displays the complete pairwise comparison results.

Discussion

When compared to baseline error rates, face coverings appeared to have variable effects on speech perception abilities depending on the type of covering utilized and the presence/absence of RM system use. While the introduction of a cloth mask by itself did not yield any significant statistical change in performance for this particular group, study participants commented that they had to work harder to listen when the speaker was masked. Given the less-developed auditory systems and limited lexicons of children, it is likely that the deleterious impact on children's speech perception abilities would be more notable, particularly for children who are deaf or hard of hearing. For example, participants commented throughout the listening task that what they perceived was a nonsensical word, but would offer an alternate, similar-sounding word that was more likely to be the actual spoken word. As children typically possess less robust lexicons, it is less likely that they would be able to self-correct in the same way as adults when presented with an unfamiliar or nonsensical word. This would be an even greater issue for young children in a typical classroom setting, who not only are exposed to new vocabulary frequently, but also often are listening in background noise from distances greater than six feet. It is likely that the speaker's speech signal would become less robust with increased distance, which would consequently present additional listening challenges, particularly for children who already experience degraded auditory input (ie children who are deaf or hard of hearing and utilize assistive listening technology).

Importantly and positively, this study found that the incorporation of an RM system yielded a significant increase in performance when paired with a cloth mask or a face shield. The face shield with RM listening condition was revealed to be identical to the baseline (no face covering, no RM) condition. Additionally, both fabric mask conditions paired with remote microphone technology (the cloth mask with RM and windowed mask with RM) were statistically similar to the baseline. Although this study investigated auditory-only conditions, it is possible that the face shield and windowed mask could supplement the acoustic signal through visual access to the mouth and face. These findings agree with expected benefits of remote microphone system use for improving access to the primary speech signal.

Use of the RM did not always result in improved performance, however. Specifically, RM use with the ClearMaskTM yielded significantly poorer performance than all other test conditions. As the purpose of the RM is to make the primary speech signal more audible (ie louder) to the listener, it is hypothesized that the signal (sound exiting the mask and picked up by the microphone) underwent greater distortion with the ClearMaskTM than the cloth mask, as demonstrated by opposing effects on error rates (see Figure 2). When the signal entering the RM is not interrupted by the facial covering, such as with the face shield, performance increases as expected with RM use.

While it is true that clear face masks can be advantageous for lip reading, these findings alert the reader to consider the impact of the facial covering on the auditory signal for each child, the importance of assessing which covering might yield the best listening condition for any particular child, and whether the RM is enhancing or distorting the auditory signal. To determine the best listening condition, a functional listening assessment can be accomplished by reading a list of 25 minimally contrasting single-syllable words and tracking the number of words the child is able to perceive correctly with and without the remote microphone technology paired with the face covering. One also could utilize the functional listening evaluation (FLE) available through Phonak for a more objective measure of listening ability in a student's everyday environment (Johnson, 2013). For classrooms that utilize frequency modulated (FM) systems rather than DM remote microphone systems, a functional listening assessment would be of equal or greater importance given the increased susceptibility of FM systems to interference. When the child has the language to report on his/her listening conditions, the child's feedback regarding sound quality is also likely to be valuable.

In order to eliminate the potential for decreased speech perception abilities as demonstrated with the ClearMaskTM, while at the same time providing increased protection from airborne particles, a modified face shield paired with a RM will be utilized by all teachers and staff at the Moog Center when returning to school in August. The modified face shield includes an apron made of triple-layered fabric, which allows staff to curb transmission of viral droplets (WHO, 2020). More information related to the modified face shield with apron can be found in the appendix.

As school personnel navigate new guidelines for protecting the health and safety of teachers and students while needing to meet the educational needs of the children, quality access to classroom instruction presented orally is essential, particularly for students who are deaf or hard of hearing. When considering personal protective equipment for teachers to use in the classroom, thought must be given not only to the amount of visual access provided by the facial covering material but to the impact of that material on sound quality provided to the listener and how it is impacted by remote microphone use.

Important findings:

- Perception of speech from a teacher who wore a face shield with a remote microphone was nearly identical to perception from the baseline condition.
- Perception of speech from a teacher who wore a ClearMaskTM with a remote microphone was significantly poorer than perception both from the same mask without remote microphone and from the baseline condition.

Considerations:

- Children with underdeveloped lexicons are likely to struggle more than adults when listening to a speaker wearing a face covering.
- Functional listening assessments can be implemented easily in the classroom environment to determine a best listening condition for any particular child.

Further reading

The references for this article are available on the BATOD website at: www.batod.org.uk/information/batod-association-magazine-2020

There are also two appendices:

Appendix A. What will we be using? Face Shields with Aprons

Appendix B. Making a Face Shield with Apron *with links to step-by-step instructions for making the apron.*



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