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Research Article

Listening in 2020: A Survey of Adults' Experiences With Pandemic-Related Disruptions

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Purpose: The COVID-19 pandemic has introduced lifestyle changes that may negatively impact communication, including the pervasive use of face masks and videoconferencing technology. Here, we examine the effects of age and self-rated hearing on subjective measures of speech understanding via a survey accessed by adults residing in the United States.
Method: Responses to an online survey were obtained from adults (21 years of age and older) during the summer and fall of 2020. The survey included questions about hearing and speech understanding in a variety of scenarios and different listening conditions, including when communicating with people using face masks in quiet and noisy environments and when using videoconferencing.
Results: Data from 1,703 surveys were analyzed. In general, the use of face masks led to the perception of poorer speech understanding and greater need for concentration, especially in noisy environments. When responses from all participants were considered, poorer self-rated communication ability was noted as age increased. However, among people who categorized their overall hearing as “Excellent” or “Good,” younger adults rated their speech understanding ability in noisy situations as poorer than middle-age or older adults. Among people who rated their overall hearing as “Fair” or “Poor,” middle-age adults indicated having more difficulty communicating with people using face masks, as compared with older adults. Examination of open-ended responses suggested that the strategies individuals use when communicating with people wearing face masks vary by age and self-rated hearing. Notably, middle-age and older adults were more likely to report using strategies that could put them at risk (e.g., asking others to remove their face masks).
Conclusions: Even younger adults with self-perceived good hearing are not immune to communication challenges brought about by face masks. Among individuals with similar degrees of self-rated hearing, the expected increase in communication difficulty with age was not noted among our respondents.

The COVID-19 pandemic has led to changes in the way people communicate. In response to the pandemic, the United States Centers for Disease Control and Prevention issued guidelines that include maintaining at least a 6-ft distance from other people and using a face covering in public settings (Centers for Disease Control and Prevention, 2021). Because of the need to reduce face-to-face communication, more people than ever are relying on videoconferencing technology to work and to socialize.

Although these adaptations were developed with an eye toward reducing the spread of the virus, they have substantial negative impacts on how easily many individuals can communicate. Imposing a distance between a listener and a talker decreases the physical intensity of the message. This can be particularly problematic for people with hearing loss, who already are coping with reduced audibility of speech signals. Increasing the distance between the talker and listener can be especially demanding for hearing-impaired people in noisy rooms with multiple people talking at the same time (e.g., Westermann & Buchholz, 2015).

Perhaps even more disruptive is the use of face coverings. Conventional face masks make it impossible for individuals to use lipreading cues to augment the auditory message, although visual information provided by other parts of the face, which can help convey information, may still be available (e.g., Fecher & Watt, 2013; Lansing & McConkie, 1999; Thomas & Jordan, 2003). Lipreading is particularly important when communicating in a noisy environment, especially for people with hearing loss (e.g., Gordon & Allen, 2009; Jesse & Janse, 2012).

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Face coverings also can lead to distortion of the speech signal, primarily via attenuation of high-frequency information. Research has demonstrated that masks act like low-pass filters, with the amount of attenuation depending on the type of mask. Paper surgical masks tend to lead to less attenuation than either N95 masks (Goldin et al., 2020; Palmiero et al., 2016) or cloth masks, with the amount of attenuation from cloth masks varying substantially depending on the type of material used and the number of layers (Corey et al., 2020). Although they provide potentially beneficial visual speech cues, plastic face shields and masks with clear plastic windows appear to lead to the greatest amount of speech signal distortion (Corey et al., 2020; Rudge et al., 2020). Face masks can disrupt speech perception even in young, normal-hearing adults when there is noise present (Fecher & Watt, 2013; Wittum et al., 2013). The use of a face mask in a quiet environment may have little effect on speech intelligibility for young, normal-hearing listeners (Llamas et al., 2009; Rudge et al., 2020) but can lead to a decrease in speech understanding for people with hearing loss, especially when that hearing loss is severe to profound (Atcherson et al., 2017). Results of a recent study (Truong et al., 2021) found that participants (young adults with normal hearing) recalled fewer words from sentences when the talker was using a face mask versus when the talker was not using a mask, even though intelligibility of the sentences was close to ceiling (around 99%) in both conditions. This suggests that speech produced with a face mask requires additional processing resources from the listener, leaving fewer resources for encoding a message into memory. However, it should be kept in mind that talkers may compensate when wearing a face mask by increasing their vocal intensity and/or speaking in an intentionally clear manner. These modifications may help mitigate mask-produced filtering and the lack of visual cues (Mendel et al., 2008).

People have turned to videoconferencing as a way to keep in touch and keep working during the COVID-19 pandemic. A recent paper by Naylor et al. (2020) found that the adults with hearing loss they surveyed were using videoconferencing more frequently during the COVID-19 lockdown than they did previously. Videoconferencing can lead to a host of challenges to communication. Less-than-ideal connections can cause asynchrony between a talker's speech and the lipreading cues that are viewed by the listener. This type of asynchrony can be especially detrimental to older adults listening in the presence of noise, whether or not they have hearing loss (e.g., Gordon-Salant et al., 2017). Older adults have poorer computer literacy in general (e.g., A. N. Moore et al., 2015) and video calls with multiple participants may be especially difficult for older individuals (e.g., Choi & Wong, 2018) due to age-related decline or lag in attention switching (see reviews by Gajewski et al., 2018; Wasylyshyn et al., 2011).

Several recent reports shed light on how pandemic-related changes affect people with hearing loss. Trecca et al. (2020) noted that 44% of their adult participants (M_{age} = 60 years) who visited an emergency room were impacted by reduced acoustic transmission from face masks, and 56% perceived that they were negatively affected by an inability to lipread people using face masks. Naylor et al. (2020) reported results of a survey of 129 adults (M_{age} = 64 years) with hearing loss living in Scotland. That paper, which focused on people's responses to pandemic-related disruptions, laid out the negative impacts that these disruptions have caused in the lives of their participants with hearing loss. These impacts included difficulty communicating with people who are wearing face masks, increased worrying about communication, and disengaging from conversations. Saunders et al. (2020) reported results of a survey of 460 adults 18–89 years of age that was conducted in the summer of 2020. They found that the use of face coverings not only affected speech perception but also had negative consequences for how people felt about communicating (e.g., reduction in willingness to communicate, increased anxiety and stress), especially for people with hearing loss. Critically, these negative impacts of using face coverings were noted for both talkers and listeners.

We were interested in learning about people's perceptions of pandemic-related disruptions in communication in terms of both self-perceived speech understanding and self-perceived listening effort. Individuals who can adequately understand speech (or who perceive that they can do so) may need to expend differential amounts of listening effort in order to achieve that level of understanding (see the special edition of *Ear and Hearing* [Volume 37, 2016] for a comprehensive overview of listening effort). Ratings of effort may be especially useful to obtain when objective performance is close to ceiling (e.g., T. M. Moore & Picou, 2018; Zekveld & Kramer, 2014). For example, younger and middle-age adults may be able to perform with similar levels of accuracy on a speech recognition task, but the middle-age individuals may need to expend more effort in doing so (e.g., Degeest et al., 2015; Helfer, Freyman, et al., 2020; Helfer, van Emmerik, et al., 2020). Older adults may be inclined to underestimate self-reported listening effort (e.g., Larsby et al., 2005), even though behavioral measures often reveal greater listening effort on the part of older versus younger adults (e.g., Gosselin & Gagne, 2011). Here, we examine both self-rated hearing difficulty and self-rated effort in an attempt to more comprehensively define individuals' perception of their overall communication ability.

This article describes the results of a rapid online survey (e.g., Geldsetzer, 2020) conducted during the summer of 2020 that probed the impact of face masks and videoconferencing on speech understanding. The survey was completed in two phases: Phase 1 targeted middle-age and older adults, while in Phase 2, we collected responses from younger adults. Surveys were obtained from 1,168 individuals aged 40 years and older in Phase 1 and 535 adults aged 21–35 years in Phase 2. Participation was restricted to individuals residing in the United States. The survey focused on how well people could understand speech with and without the talker using a face mask, in quiet and noisy environments. It also probed how well people believed they could understand during video calls in quiet and noisy rooms.

Furthermore, we determined how much concentration participants believed they needed to use in those situations, as a proxy for self-assessed listening effort. Respondents were invited to add open-ended comments regarding strategies they find helpful when talking to people wearing masks or while participating in video calls. We were particularly interested in comparing impacts across age (younger, middle-aged, and older adults) and self-perceived hearing ability, as well as exploring the influence of hearing device (hearing aids and cochlear implants) use.

Method

Survey Information

A survey was developed in the summer of 2020 to collect data from adults living in the United States. An initial pilot version of the survey was sent to a small number of people; based on feedback from that process, the wording of some questions was clarified and the response format was simplified. The final version of the survey can be accessed in Supplemental Material S1. The first section of the survey contained 15 questions about demographics (age, ethnicity, gender, educational level, state of residence), self-perceived hearing, vision, and general health. Self-perceived hearing was rated on a 4-point scale (*Excellent*, *Good*, *Fair*, or *Poor*). Individuals who rated their hearing as anything other than *Excellent* also were asked about hearing aid and cochlear implant use.

Following these questions was a series of probes about experiences in three scenarios: running errands or going to appointments outside the home, working outside the home, and socializing face to face. Respondents were asked how often they were in these scenarios both before the COVID-19 pandemic and during the pandemic. Participants who answered that they were never or almost never in one of these scenarios currently (i.e., at the time of they took the survey) skipped to the next scenario. All other participants were asked to evaluate how well they thought they could understand speech in four situations for each scenario: in a quiet place when they could see the other person's face completely, in a quiet place when the other person was using a face mask, in a noisy place when they could see the other person's face completely, and in a noisy place when the other person was using a face mask. Participants responded on a 5-point Likert scale with points on the scale labeled as *I usually have a lot of difficulty understanding* (1), *I usually have some difficulty understanding* (3), and *I usually can understand everything or almost everything* (5). Respondents also were given the option of *Don't know/not applicable*; these responses were excluded from data analysis. The survey then asked about how much respondents thought they needed to concentrate in each of these four situations by using a 5-point Likert scale with points marked as *I need to concentrate very little* (1), *I need some concentration* (3), and *I need to concentrate a lot* (5). Respondents were instructed that if they use any hearing devices most of the time, their answers should indicate their listening ability when using the device(s).

The final set of scenarios focused on the use of videoconferencing. Participants who responded that they did not use videoconferencing for work or for socializing skipped those prompts. All other respondents were asked to rate their ability to understand and their need to concentrate on video calls when they were in a quiet room and when they were in a noisy room. This was done separately for the use of videoconferencing for work and for using videoconferencing for socializing. Following these items were open-ended questions asking respondents to indicate strategies that they find especially helpful when talking to someone wearing a face mask and strategies that they find especially helpful when listening on a video call or videoconference.

The survey was hosted on the Qualtrics platform. Participants were directed to the survey by clicking on a link within an ad (see advertising details below). Participants could register their e-mail addresses, via a separate anonymous survey, for the opportunity to win an iPad (for Phase 1 of the survey) or an Amazon gift card (for Phase 2 of the survey). The survey was approved by the University of Massachusetts Institutional Review Board (protocol ID 2203). Participants gave informed consent before completing the survey.

Participants

We used two advertising strategies during Phase 1 in order to sample middle-age (40–64 years) and older (≥ 65 years) adults with and without hearing loss. First, to specifically target individuals with hearing loss, we enlisted Hearing Tracker (a company that provides nonbiased information about hearing aids to consumers) to advertise for respondents. Hearing Tracker included information about our survey in their e-mailed newsletter (sent to approximately 10,000 users) and posted information about the survey on their Facebook page and in their Hearing Aid Forum private Facebook group. Second, we used Facebook Ads to recruit a broader respondent pool within this age range. The Facebook advertising campaign, which was targeted at adults 40 years and older who lived in the United States, ran for a period of 1 month (July 19, 2020, to August 20, 2020). The Facebook ad reached 46,447 individuals with 1,341 people clicking on the ad.

Phase 2 of the survey was designed to obtain responses from younger adults, primarily to provide a comparison with data collected from middle-age and older adults. We used a Facebook ad campaign for 7 days (September 26, 2020, to October 2, 2020) that targeted people 21–35 years of age residing in the United States. The ad was delivered to 17,760 people with 790 individuals clicking on the ad.

A summary of the demographic data from our respondents can be found in Table 1. Responses to the demographic questions showed different distributions of ethnic identities and gender across the age groups. Diversity of our respondent pool decreased as age increased: 69.5% of the younger participants, 87.9% of the middle-age participants, and 97.2% of the older participants identified themselves as only Caucasian. Both younger and middle-age groups had disproportionately large numbers of female respondents,

Table 1. Demographic data for survey respondents as *n* (percent within age category).

Data	Younger	Middle-age	Older
Gender			
Male	50 (9.4)	129 (28.7)	368 (54.0)
Female	448 (84.1)	337 (75.1)	311 (45.7)
Nonbinary/other	35 (6.6)	3 (0.7)	2 (0.1)
Ethnicity			
Asian	74 (14.1)	12 (2.6)	3 (0.5)
Black	23 (4.4)	19 (4.2)	5 (0.7)
Caucasian	364 (69.5)	400 (88.9)	642 (97.3)
Latinx	29 (5.5)	11 (2.4)	3 (0.5)
Native American	1 (0.2)	2 (0.7)	5 (0.8)
Pacific Islander	0 (0.0)	2 (0.4)	1 (0.2)
More than one	33 (6.3)	8 (1.8)	1 (0.2)
Highest education			
Some high school	2 (0.4)	1 (0.2)	2 (0.3)
HS diploma/GED	26 (4.9)	35 (7.3)	49 (7.1)
Some college	107 (20.0)	113 (23.6)	175 (25.4)
College degree	400 (74.8)	324 (67.8)	462 (67.0)
Self-rated hearing			
Excellent	236 (44.1)	89 (18.6)	50 (7.2)
Good	299 (55.9)	160 (33.5)	136 (19.7)
Fair	—	105 (22.0)	248 (35.9)
Poor	—	124 (25.9)	256 (37.1)
HA or CI use*			
Yes	—	190 (39.7)	472 (68.4)
No	—	288 (60.3)	218 (31.6)

Note. Data do not include individuals who selected "prefer not to answer." Em dashes indicate data not available. HS = high school; GED = General Educational Development; HA = hearing aid; CI = cochlear implant.

*Individuals rating their hearing as "Excellent" were not asked about hearing device use.

while the older group was closer to being reflective of the gender distribution in the general population.

Data Analyses

In Phase 1, a total of 1,224 people accessed the survey and consented to participate (via a radio button on the first page of the survey). After eliminating responses from ineligible individuals (those younger than 40 years of age or not residing in the United States) and forms that were completed only through the demographic and hearing/health/vision questions, there were 1,168 usable surveys. In Phase 2, 639 individuals opened the survey and indicated their consent, and there were 604 surveys that yielded usable data (i.e., respondents who lived in the United States, were in the target age range, and completed questions beyond the demographic items). Since the primary purpose of obtaining responses from younger individuals was to provide a normal-hearing comparison group, data were eliminated from individuals who indicated that they used hearing aids ($n = 4$) or cochlear implants ($n = 1$). Responses from younger individuals who rated their hearing as "fair" or "poor" also were deleted prior to analysis ($n = 66$). Hence, data discussed below are from a total of 1,703 individuals: 535 younger adults, 478 middle-age (40–64 years) adults, and 690 older (> 64 years) adults.

To simplify the data analysis, self-rated hearing was categorized as being either *better* (ratings of "Excellent" or "Good") or *poorer* (ratings of "Fair" or "Poor") based on individuals' response to the prompt, "How would you rate your hearing?". Data were analyzed using repeated-measures analysis of variance (ANOVA) with Bonferroni post hoc tests to correct for multiple comparisons[1] in order to examine the effects of age group and self-rated hearing. The influence of hearing devices (hearing aids or cochlear implants) was examined by comparing responses of people in the *poorer* hearing category who indicated that they did or did not use these devices.

There were 979 surveys that included a response to the question: *"Are there any strategies that you find especially helpful when talking to someone who is wearing a face mask? If so, please list them below."* A step-by-step thematic analysis process was undertaken to define and observe patterns in the open-ended response data (Braun & Clarke, 2006). These open-ended responses were analyzed by two members of the research team (S. K. M. and S. T.) through an iterative process of developing a codebook that captured the range of responses provided to the prompt. To develop the codebook, the two researchers applied a code (that they created and defined independently) to every line of the open-ended responses. Those coded responses were compared and discussed between the two researchers until a single set of codes was established. The codebook included an operational definition for each code, an exemplar quote for each code, and an example of what would not be covered by each code. After the manual coding process, the two team members engaged in a thematic analysis of the codes to identify categories of strategies described by the respondents. A software package designed for qualitative data and mixed-methods analyses, MAXQDA (VERBI Software), was used to sort all open-ended responses by their codes and by key demographics. The open responses were uploaded in MAXQDA with demographic identifiers for each open-ended comment (age, self-reported hearing status, and hearing aid/cochlear implant user status). A mixed-methods approach was undertaken to analyze patterns of responses per key participant groups investigated in the quantitative analysis. There were relatively few responses to the open-ended question about strategies for videoconferencing, so these were not analyzed.

Results

Self-Rated Speech Understanding

Participants were asked to rate their ability to understand speech under four conditions: in quiet when the talker's face was visible, in quiet when the talker was using a face mask, in a noisy room when the talker's face was visible, and in a noisy room when the talker was using a face mask. For some categories of participants (particularly older adults with poorer hearing), there were relatively few

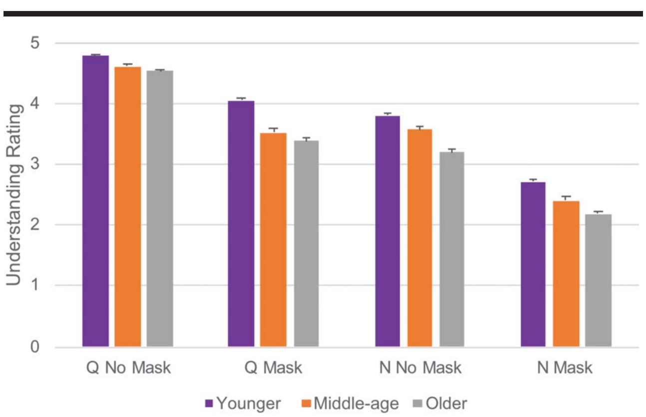
[1]Justification for using parametric statistics to analyze Likert-scale data can be found in Mircioiu & Atkinson (2017) and Norman (2010).

respondents who currently worked outside the home, so responses to that specific prompt were not analyzed. Visual inspection of the data revealed generally similar patterns for the other two scenarios (errands/appointments and face-to-face socializing). Therefore, responses to those two scenarios were averaged for all subsequent data analyses.

We first analyzed data from all participants, aggregated by age category only (younger, middle-age, older). These data can be seen in Figure 1; results of all ANOVAs are shown in Table 2. We found expected results for age group, use of face masks, and acoustical condition (quiet vs. noisy environment)—both face masks and noise had negative impacts on speech understanding, and speech understanding decreased as age increased. The combination of the use of face masks and a noisy environment led to a substantial reduction in self-perceived speech understanding for all groups of respondents. Repeated-measures ANOVA with acoustic condition (quiet vs. noise) and face mask (yes vs. no) as within-subjects factors and age as a between-subjects factor showed highly significant ($p \leq .001$) main effects for all variables. For this and all other analyses, effect sizes (Partial η^2) were large (≥ 0.14) for the main effects of acoustic condition and mask condition and small (~.01) or medium (~.06) for the main effects of age group and device use, as well as for most interactions (see Table 2). Post hoc one-way ANOVA with Bonferroni correction found that younger participants rated their speech understanding ability as better than middle-age and older adults in all conditions. All interactions also were statistically significant.

A similar set of analyses was conducted with the data from the *better* hearing participants, who came from all three age groups. This comparison can be seen in Figure 2. Repeated-measures ANOVA on the self-rated understanding data was conducted with mask condition and acoustic condition as within-subjects factors and age group as the between-subjects factor. All three main effects were

Figure 1. Mean ratings for prompts from all respondents regarding how well they can understand speech in a quiet place (Q) and in a noisy place (N) when the other person is (mask) or is not (no mask) using a face covering. The scale that the participants used for these prompts was bounded by *I usually have a lot of difficulty understanding* (1) to *I usually can understand everything or almost everything* (5). Error bars represent the standard error.



significant beyond the .001 level. Additionally, there was a significant three-way interaction ($p = .021$). Post hoc one-way ANOVAs with Bonferroni correction showed that the difference between groups was statistically significant for the two noise conditions. Unexpectedly, in both these cases, younger adults indicated that they had poorer self-rated speech understanding (vs. the middle-age group with no mask and vs. both other groups with masks).

Next, we examined responses from participants who rated their overall hearing as “fair” or “poor”; note that all of these individuals were middle age or older. These participants were further divided into those who use hearing aids and/or cochlear implants and nonusers of amplification devices (see Figure 3). Repeated-measures ANOVA was conducted on the self-rated understanding data with mask (yes or no) and acoustic condition (quiet or noise) as within-subjects factors and age group (middle-age or older) and device use (user or nonuser) as between-subjects factors. Results showed significant main effects of acoustic condition, mask condition, and device use (all $p < .001$). Device users indicated poorer self-rated speech understanding as compared with nonusers. There also were several significant interactions, including Mask Condition × Age Category ($p = .016$) and Acoustic Condition × Mask Condition × Device Use ($p = .014$). Post hoc analysis of the Mask Condition × Age interaction showed that although the two age groups did not differ significantly in the no-mask conditions, the middle-age participants rated their ability to understand speech as poorer than the older participants in both quiet and noise when a face mask was used.

Self-Rated Concentration

Participants also were asked to rate how much concentration they needed to use to understand speech in the various scenarios. Analysis of these ratings found similar trends to those discussed above for ratings of speech understanding (see Table 2). Figures depicting the Concentration ratings can be accessed in the Appendix. ANOVAs on data for all participants found significant main effects for all variables (age group, acoustic condition, and mask condition) as well as a significant three-way interaction (all $p < .001$). Post hoc one-way ANOVAs with Bonferroni correction found that younger participants indicated the need for less concentration in all conditions, as compared with the other two groups. Additionally, the middle-age participants demonstrated the need for significantly less concentration than the older respondents in the noise/no-mask condition.

Self-rated concentration data from respondents in the *better* hearing category also were analyzed with repeated-measures ANOVA. Results showed significant main effects for all variables (noise condition and mask condition: $p < .001$; age category: $p = .016$). There also were significant interactions between Noise Condition × Age Category ($p < .001$) and Noise Condition × Mask Condition ($p < .001$). In both noise conditions (with and without a face mask), younger participants indicated greater need for concentration than either the middle-age or older respondents.

Table 2. Analysis of variance results.

Understanding	*F*	*df*	*p*	Partial η^2
All respondents				
Noise	2972.74	1, 1435	< .001	.674
Mask	2062.62	1, 1435	< .001	.590
AgeCat	50.92	2, 1435	< .001	.066
Noise × AgeCat	6.88	2, 1435	.001	.010
Mask × AgeCat	8.08	2, 1435	< .001	.011
Noise × Mask	11.09	1, 1435	.001	.008
Noise × Mask × AgeCat	35.55	2, 1435	< .001	.045
Better hearing				
Noise	1296.85	1, 804	< .001	.617
Mask	736.07	1, 804	< .001	.478
AgeCat	6.82	2, 804	< .001	.017
Noise × AgeCat	9.22	2, 804	< .001	.022
Mask × AgeCat	0.53	2, 804	.586	.001
Noise × Mask	52.64	1, 804	< .001	.061
Noise × Mask × AgeCat	3.86	2, 804	.021	.010
Poorer hearing				
Noise	679.14	1, 627	< .001	.520
Mask	658.77	1, 627	< .001	.512
AgeCat	1.55	1, 627	.214	.002
Device	7.78	1, 627	< .001	.053
Noise × AgeCat	0.79	1, 627	.374	.001
Noise × Device	3.80	1, 627	.052	.006
Mask × AgeCat	5.81	1, 627	.016	.009
Mask × Device	7.65	1, 627	.006	.012
Noise × Mask	3.88	1, 627	.049	.006
AgeCat × Device	0.76	1, 627	.383	.001
Noise × AgeCat × Device	0.03	1, 627	.959	.000
Mask × AgeCat × Device	1.29	1, 627	.256	.002
Noise × Mask × AgeCat	1.56	1, 627	.212	.002
Noise × Mask × Device	6.04	1, 627	.014	.010
4-way	1.21	1, 627	.272	.002
Concentration	***F***	***df***	***p***	**Partial η^2**
All respondents				
Noise	1823.31	1, 1424	< .001	.561
Mask	1568.08	1, 1424	< .001	.524
AgeCat	34.98	2, 1424	< .001	.047
Noise × AgeCat	13.26	2, 1424	< .001	.018
Mask × AgeCat	2.79	2, 1424	.062	.004
Noise × Mask	1.29	1, 1424	.257	.001
Noise × Mask × AgeCat	15.64	2, 1424	< .001	.021
Better hearing				
Noise	782.12	1, 803	< .001	.493
Mask	654.99	1, 803	< .001	.449
AgeCat	4.13	2, 803	.016	.010
Noise × AgeCat	17.23	2, 803	< .001	.041
Mask × AgeCat	1.24	2, 803	.289	.003
Noise × Mask	18.09	1, 803	< .001	.022
Noise × Mask × AgeCat	0.63	2, 803	.535	.002
Poorer hearing				
Poorer hearing				
Noise	375.79	1, 617	< .001	.379
Mask	394.21	1, 617	< .001	.390
AgeCat	1.59	1, 617	.208	.003
Device	17.90	1, 617	< .001	.028
Noise × AgeCat	0.05	1, 617	.832	.000
Noise × Device	0.08	1, 617	.774	.000
Mask × AgeCat	2.15	1, 617	.143	.003
Mask × Device	0.99	1, 617	.320	.002
Noise × Mask	3.81	1, 617	.051	.006
AgeCat × Device	2.09	1, 617	.382	.001
Noise × AgeCat × Device	0.00	1, 617	.957	.000
Mask × AgeCat × Device	0.20	1, 617	.656	.000
Noise × Mask × AgeCat	1.12	1, 617	.290	.002
Noise × Mask × Device	3.08	1, 617	.080	.005
4-way	0.23	1, 617	.632	.000

(*table continues*)

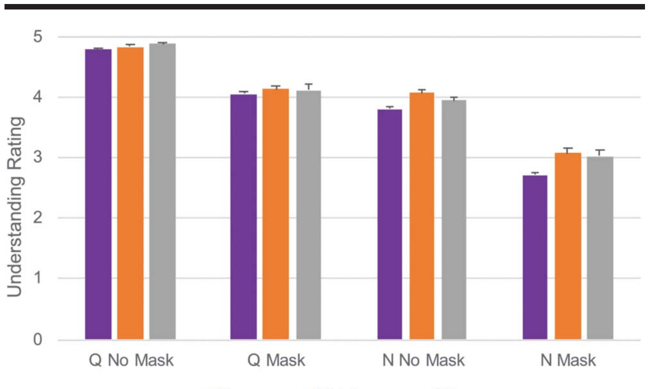
Table 2. *(Continued).*

Videoconferencing	*F*	*df*	*p*	Partial η^2
Better hearing: Understand				
Noise	644.96	1, 660	< .001	.494
AgeCat	6.04	1, 660	.003	.018
Noise × AgeCat	12.31	2, 660	< .001	.036
Better hearing: Concentrate				
Noise	506.95	1, 662	< .001	.434
AgeCat	5.07	1, 662	.007	.004
Noise × AgeCat	1.45	2, 662	.235	.015
Poorer hearing: Understand				
Noise	445.16	1, 408	< .001	.522
AgeCat	4.87	1, 408	.004	.020
Device	10.87	1, 408	.093	.026
Noise × AgeCat	3.18	1, 408	.075	.008
Noise × Device	0.85	1, 408	.358	.002
AgeCat × Device	0.46	1, 408	.496	.001
Noise × AgeCat × Device	0.17	1, 408	.685	.000
Poorer hearing: Concentrate				
Noise	257.39	1, 410	< .001	.386
AgeCat	5.08	1, 410	.025	.012
Device	5.97	1, 410	.015	.014
Noise × AgeCat	0.09	1, 410	.760	.000
Noise × Device	0.14	1, 410	.710	.000
AgeCat × Device	1.10	1, 410	.294	.003
Noise × AgeCat × Device	0.77	1, 410	.382	.002

Note. Noise = noisy vs. quiet room; Mask = presence vs. absence of face mask; AgeCat = younger vs. middle-age vs. older (for all respondents and better hearing) or middle-age vs. older (for poorer hearing); Device = users of hearing aids or cochlear implants vs. nonusers.

ANOVA on the self-rated concentration data from the respondents with *poorer* hearing indicated significant main effects for mask condition, noise condition, and device use, with a nonsignificant effect of age group (p = .208) and no significant interactions. In all conditions people who used amplification devices indicated greater need for concentration than non–device users.

Figure 2. Mean ratings for prompts from respondents who self-rated their hearing as “Excellent” or “Good” regarding how well they can understand speech in a quiet place (Q) and in a noisy place (N) when the other person is (mask) or is not (no mask) using a face covering. The scale that the participants used for these prompts was bounded by *I usually have a lot of difficulty understanding* (1) to *I usually can understand everything or almost everything* (5). Error bars represent the standard error.

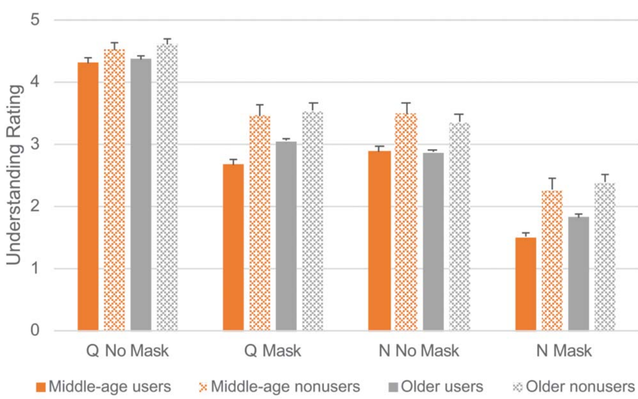


Videoconferencing

Participants were asked to indicate how well they are able to understand what someone is saying when using videoconferencing (e.g., Facetime, Zoom) when there are no technological problems, in a quiet room and in a noisy room. In separate prompts, they were asked to indicate how much they needed to concentrate to understand the message when using videoconferencing in these environments. These two sets of prompts were completed separately for using videoconferencing for work and using it for socializing. Since similar patterns were noted for responses to these two scenarios, data were averaged across the scenarios prior to analysis. Below, we present data for the groups aggregated by self-rated *better* hearing versus *poorer* hearing.

Figure 4 displays responses from the *better* hearing group, with speech understanding in the left set of bars and concentration in the right set of bars. It can be observed that respondents across all three age groups expressed little difficulty understanding messages via videoconferencing a quiet room but found this to be substantially more challenging in a noisy room. ANOVA and post hoc analysis for these data showed significant main effects for noise condition (p < .001) and age group (p = .003), with a significant interaction (p < .001), as the younger participants rated their speech understanding ability to be poorer than either the middle-age or older groups in noisy environments. ANOVA on the self-rated concentration data (right set of bars) showed significant main effects of noise condition (p < .001) and age group (p = .007). More concentration was needed

Figure 3. Mean ratings for prompts from respondents who self-rated their hearing as "Fair" or "Poor," aggregated by age category and by hearing aid/cochlear implant use (users vs. nonusers) regarding how well they can understand speech in a quiet place (Q) and in a noisy place (N) when the other person is (mask) or is not (no mask) using a face covering. The scale that the participants used for these prompts was bounded by *I usually have a lot of difficulty understanding* (1) to *I usually can understand everything or almost everything* (5). Error bars represent the standard error.



in a noisy room, and younger participants indicated a need for greater concentration than either middle-age or older adults.

Figure 5 displays the responses to the videoconferencing prompts from individuals with self-rated *poorer* hearing. ANOVA on the self-rated understanding data showed significant main effects for noise condition ($p < .001$) and age group ($p = .004$) with no significant interactions. Middle-age respondents indicated poorer speech understanding when using videoconferencing, as compared with older respondents. ANOVA on the concentration data revealed significant main effects of noise condition ($p < .001$), age category ($p = .012$), and device use ($p = .014$). Figure 5 demonstrates that middle-age adults had a greater need for concentration than older adults, and nondevice users had less need for concentration, as compared with device users.

Figure 4. Mean ratings for prompts from respondents who self-rated their hearing as "Excellent" or "Good" for videoconferencing in quiet (Q) and noise (N). The scale that the participants used for the Understand prompts was bounded by *I usually have a lot of difficulty understanding* (1) to *I usually can understand everything or almost everything* (5). The scale that the respondents used for the Concentrate prompts was bounded by *I need to concentrate very little* (1) to *I need to concentrate a lot* (5). Error bars represent the standard error.

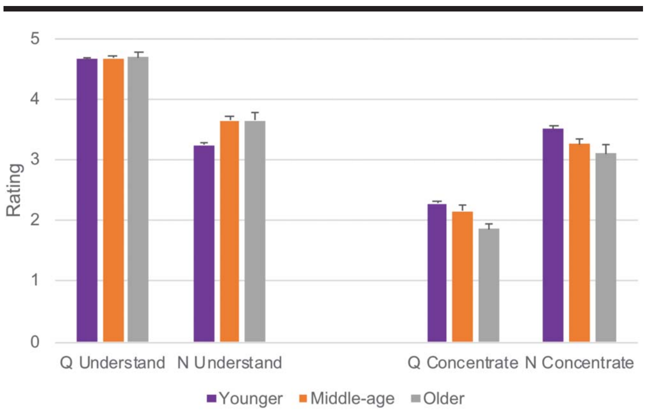
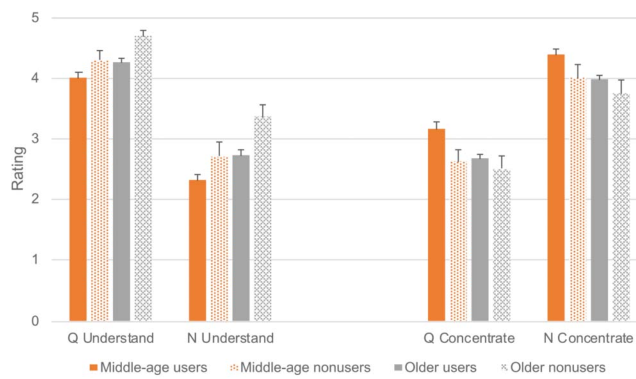


Figure 5. Mean ratings for prompts from respondents who self-rated their hearing as "Fair" or "Poor" for videoconferencing in quiet (Q) and noise (N). The scale that the participants used for the Understand prompts was bounded by *I usually have a lot of difficulty understanding* (1) to *I usually can understand everything or almost everything* (5). The scale respondents used for the Concentrate prompts was bounded by *I need to concentrate very little* (1) to *I need to concentrate a lot* (5). Error bars represent the standard error.



Open-Ended Responses

Participants were asked to provide open-ended responses via the prompt "*Are there any strategies that you find especially helpful when talking to someone who is wearing a face mask? If so, please list them below.*" Of the 979 total valid responses across all three age groups, 314 responses (32.1%) were from younger adults, 270 responses (27.6%) were from middle-age adults, and 395 responses (40.3%) were from older adults. All responses were uploaded in MAXQDA and coded through an iterative process. After combining codes through a thematic analysis process, five major categories were created, which covered 72.6% of all the open-ended responses (see Table 3). *Active repair strategies* consisted of codes related to asking the talker to speak louder, clearer, and/or repeat what was said. *Nonverbal strategies* were codes related to facing the talker, focusing attention on the talker, and watching gestures and facial cues. *Written/captions* comprised codes related to using technology for real-time transcribing or relying on paper/pencil or phone texts to communicate. *Advocate* consisted of responses that indicated the respondent telling the talker in advance of communication problems that they have a hearing loss and or difficulty understanding. Lastly, *Environmental strategies* were codes related to adjusting one's position or reducing the background noise. Figure 6 displays the number of responses that fell into each of these five major categories.[2]

[2]An individual respondent may have multiple codes applied to their response.

Table 3. Major categories from the open-ended survey response to the question: *Are there any strategies that you find especially helpful when talking to someone who is wearing a face mask? If so, please list them below.*

Major categories	Codes	Exemplar quotes	Younger	Middle-age	Older
Active repair strategies	Clear Loud Repeat	*"…I ask them to repeat or rephrase…"* *"I usually have to ask them to speak louder, articulate better, speak more slowly"*	118	100	142
Nonverbal strategies	Face to face Active listen Nonverbals	*"Looking at the person face to face when we both has* [sic] *masks on."* *"Look in their eyes and read their body language. Focus on them only, and try to drown out distractions"*	137	63	92
Written/captions	Transcribe Write	*"I use a captioning app on my iPad, so I can listen and read what is being said. It takes a little longer to understand I have difficulty responding before the conversation moves on, but at least I understand more."* *"Asking them to write down what they want to say."*	4	32	46
Advocate	Advocate	*"I tell them I have a severe hearing loss, wear hearing aids and usually read lips…"* *"I have printed on my plain gray mask, 'DEAF' with arrows pointing to my left ear and 'hears a little' pointing to my right ear. For my purple mask, I bought pins. One says, I AM DEAF and I added arrows toward my left ear. The other button says, I AM HARD OF HEARING PLEASE KEEP YOUR MASK ON AND SPEAK UP. I have received compliments on both."*	4	25	51
Environmental strategies	Position Environment	*"Turn my ear toward them"* *"Resort to an area with less noise…and move an ear closer to the person."*	28	23	16

Note. The quantitative data reflect the number of participants per age category in each of the major categories.

The five major categories also were reviewed per participant characteristics of age group, self-rated hearing, and device use. By cross-tabbing the major categories for each age group, we observed that nonverbal strategies were the most common responses for the younger adults (43.6% of younger adults who made comments included this type of strategy), whereas among middle-age and older adults, it was most common to report using active repair strategies (37.0% and 35.9%, respectively). Eighty of the respondents had the code *advocate* applied to their response, which indicated that the person disclosed their hearing difficulties at the onset of the communication exchange. Of these 80 responses, 63.8% were from older adults compared with 31.3% from middle-age and 5.0% from younger adults. Furthermore, individuals who had *poorer* self-rated hearing were more likely to advocate in advance (16.1% of 446 respondents) versus people who had *better* self-rated hearing (1.5% of 533 respondents).

Figure 6. Number of responses in each of the top five categories to the prompt, *"Are there any strategies that you find especially helpful when talking to someone who is wearing a face mask? If so, please list them below."* One response could have multiple codes, and therefore categories, applied to it. These five categories cover 711 of the 979 respondents who included open-ended comments.

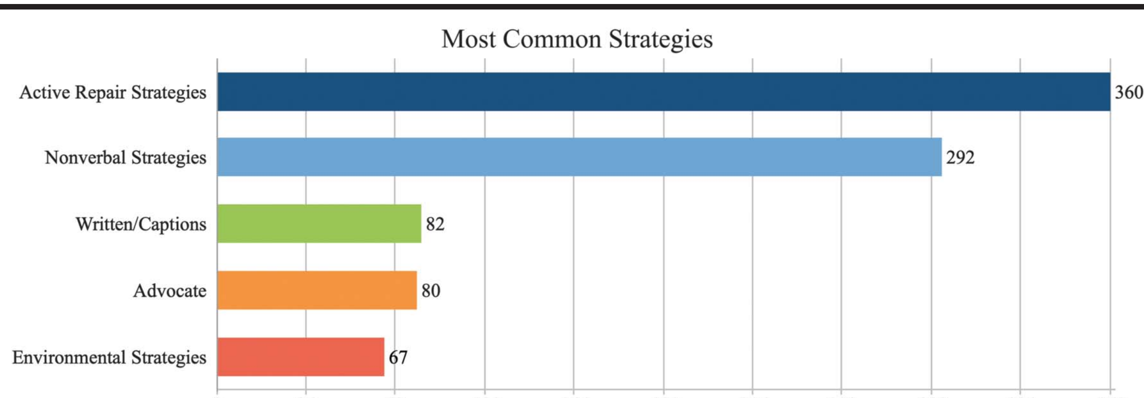


Table 4. Analysis of variance results by age category, ethnicity, and gender.

Better hearing: by ethnicity	***F***	***df***	***p***	**Partial η^2**
Condition	40.34	3, 761	< .001	.137
AgeCat	0.51	2, 763	.602	.001
Ethnicity	0.82	6, 763	.553	.006
AgeCat Ethnicity	1.22	10, 763	.272	.016
Condition × AgeCat	1.06	6, 1524	.383	.004
Condition × Ethnicity	0.59	18, 2289	.910	.005
Condition × AgeCat × Ethnicity	1.01	30, 2289	.447	.013
Poorer hearing: by ethnicity	***F***	***df***	***p***	**Partial η^2**
Condition	41.75	3, 597	< .001	.173
AgeCat	0.70	1, 599	.403	.001
Ethnicity	1.33	5, 599	.249	.011
AgeCat × Ethnicity	0.53	3, 599	.660	.003
Condition × AgeCat	1.53	3, 597	.206	.008
Condition × Ethnicity	1.39	15, 1797	.145	.011
Condition × AgeCat × Ethnicity	1.01	9, 1797	.365	.005
Better hearing: by gender	***F***	***df***	***p***	**Partial η^2**
Condition	342.31	3, 764	< .001	.573
AgeCat	1.79	2, 766	.168	.005
Gender	0.43	1, 766	.511	.001
AgeCat × Gender	0.43	2, 766	.643	.001
Condition × AgeCat	1.92	6, 1524	.074	.007
Condition × Gender	2.22	3, 764	.085	.009
Condition × AgeCat × Gender	0.35	6, 1530	.908	.001
Poorer hearing: by gender	***F***	***df***	***p***	**Partial η^2**
Condition	747.94	3, 619	< .001	.784
AgeCat	2,20	1, 621	.361	.001
Gender	2,81	1, 621	.094	.004
AgeCat × Gender	0.10	1, 621	.755	.000
Condition × AgeCat	4.95	3, 619	.002	.023
Condition × Gender	1.58	3, 619	.192	.008
Condition × AgeCat × Gender	1.58	3, 619	.193	.008

Note. Condition = presence or absence of face masks in quiet or noisy rooms; AgeCat = age category (younger, middle-age, or older for better hearing; middle-age or older for poorer hearing).

Differences in advocating strategies were also seen with device use status. Of the participants with *poorer* hearing who were coded as advocating for themselves in advance ($n = 72$), 94.4% were hearing device users.

Although not one of the five major categories seen across all respondents, *safety* codes were reviewed across age group. Examination of these responses revealed that middle-age and older adults were more inclined than younger adults to remove their masks or ask their communication partner to remove their mask. Of the 57 responses coded as *remove,* 94.7% were from middle-age and older adults. On the other hand, both younger and middle-age/older adults reported moving closer to the talker. Of the 54 responses coded as *closer,* 44.4% came from younger adults. Additionally, 71.4% of *anti-mask* codes ($n = 14$) were responses from older adults. The *anti-mask* code was applied if the negative comments regarding the mask extended beyond the challenges related to communication, for example, *"masks are ridiculous and are used to control people, they offer NO protection."*

In many cases, participants' responses had more than one code. For example, these comments from one participant:*"I self identify that I wear hearing aids and ask them to speak a little louder and a little slower. We may revert to paper or smart phone note exchanges."* were coded as *advocate, loud, clear,* and *written.* Using MAXQDA, overlapping codes were reviewed based on the five major categories. *Active* repair strategies were often seen in responses that also included *nonverbal* strategies. Similarly, *advocate* and *active* repair strategies were often coded within the same response.

Discussion

Responses to this survey revealed both expected and unexpected findings. When the data were analyzed across the entire sample, an expected pattern of responses by age category was found, with older participants reporting the most self-rated speech understanding difficulty and need for concentration. Also, as might be expected, the small differences noted between groups in the quiet/no face mask condition were much larger when the talker used a face mask or when communication took place in a noisy environment. The data also support anecdotal reports of the compounding difficulty of understanding speech in a noisy room when the talker is using a face mask, as ratings for speech understanding and concentration both indicated how challenging this situation can be.

Analyzing the data by self-reported overall hearing led to some unanticipated results. Among the participants in the *better* hearing group, younger individuals reported significantly poorer speech understanding and greater need for concentration in the two conditions with noise (with and without face masks) as compared with middle-age and older participants. It should be noted that there were substantial differences between younger and middle-age/older participant groups in terms of both gender and ethnicity (see Table 1). Among individuals in this *better* hearing category, females represented 83.7% of the younger respondents, 70.5% of middle-age respondents, and 45.1% of older respondents. The middle-age and older groups also were less ethnically diverse. Of note was that 14.1% of younger respondents were Asian, as compared with 2.6% of middle-age participants and 0.5% of older participants. Prior research has demonstrated that there can be substantial differences in how people from different gender, racial, and ethnic groups respond to questions about their health. For example, Boerma et al. (2016) established that females tend to rate their health as being poorer than males, even though men have shorter life expectancies. Kandula et al. (2007) found that Asian adults have poorer self-reported health than White adults, even though they have fewer chronic conditions. Other studies that have found racial/ethnic differences in self-rated health include Gandhi et al. (2020), who showed that, even after adjusting for number of chronic conditions and demographic variables, Hispanic, Black, and Asian adults report their health to be poorer than do non-Hispanic White adults. One explanation offered to account for these findings is that perceptions of health may be influenced by culture or cultural identity.

Data from the participants in the *poorer* hearing category also uncovered patterns that were not necessarily anticipated. Middle-age participants reported greater self-rated speech understanding difficulty when face masks are used in both quiet and noisy environments, as compared with older adults. Since hearing loss increases with age, it might be expected that older individuals would rate their speech understanding ability as being poorer than middle-age adults. Indeed, the percentage of our respondents who rated their hearing as “poor” (rather than “fair”) was considerably higher for older adults (37.1%) than for middle-age adults (25.9%). Prior research suggests that middle-age individuals tend to overestimate their hearing problems, whereas the opposite is true for older adults (Bainbridge & Wallhagen, 2014; Helfer et al., 2017) and that could be the case here. It also is worth mentioning that the proportion of male respondents in the *poorer* hearing category was much higher in the older group (53.4%), as compared with the middle-age group (27.0%), raising the question of whether this unanticipated finding was influenced by differences in gender composition.

In order to determine whether group differences in gender and/or ethnicity influenced our results, we completed additional ANOVAs on the Understanding ratings. For these analyses, the within-subjects variable was condition (quiet/no mask, quiet/mask, noise/no mask, noise/mask) with age category and either gender or ethnicity as the between-subjects factors. Results of these analyses are presented in Table 4. There were no statistically significant findings related to gender or ethnicity, although main and interaction effects involving gender approached significance in some cases. Hence, it does not appear that the substantial differences in gender and in racial/ethnic composition among age categories in this study played much of a role in our results.

Among respondents in the *poorer* hearing category, users of hearing devices rated their self-perceived speech perception ability as lower and the need for concentration greater than did nonusers. This could be a reflection that hearing devices are only minimally helpful in overcoming these pandemic-related disruptions, but it is equally likely that differences in hearing between users and nonusers of devices contributed to this finding: only 15.6% of nonusers reported their hearing as “poor” (rather than “fair”), as compared with 59.1% of device users.

In general, response patterns to prompts about self-perceived speech understanding were very similar to those obtained for self-perceived concentration/effort. Prior work has suggested that speech understanding and listening effort do not necessarily go hand in hand, as individuals who obtain similar levels of accuracy in speech understanding may need to exert different levels of effort (e.g., Pichora-Fuller et al., 2016). It could be that our 5-point Likert-scale measures of understanding and concentration were not sensitive enough to reveal differences between these two aspects of performance. Also relevant is that individuals may confound ratings of effort with ratings of performance (T. M. Moore & Picou, 2018; Picou & Ricketts, 2018). Regardless of the reasons, in this study, asking people to self-rate concentration needed to understand speech in different scenarios added little to what was gleaned from asking them to directly assess their speech understanding.

The types of strategies our respondents reported were helpful when speaking with someone using a face mask varied by age category, self-rated hearing, and device use. In general, middle-age and older adults were more likely to use active strategies such as asking someone to repeat, while younger adults more often suggested nonverbal strategies (e.g., looking at the talker). Device users were more inclined to disclose their hearing loss to communication partners and request that the person speak loudly and clearly, as compared with nonusers. However, the fact that many younger participants mentioned strategies that helped them communicate with face mask users provides further evidence that communication problems brought about by face masks are not isolated to middle-age and older individuals or to those with hearing loss. This points to the importance of devising ways to address communication challenges for all listeners. For instance, as of August 2020, the Food and Drug Administration has begun to approve the production of transparent face masks (Consumer Affairs.com, 2020; Garone, 2020). Utilizing clear masks may be especially effective in easing communication between speakers when one or both communicants have hearing loss, as they allow access to visual speech cues. However, as mentioned earlier in this article, clear masks and face shields may produce more acoustic distortion than other types of face coverings (Corey et al., 2020; Rudge et al., 2020). A few respondents mentioned carrying masks with clear windows with them when they needed to converse in public or at an appointment.

Analysis of open-ended comments revealed that using live captioning apps or relying on written communication was one of five major categories found in our participants' responses. This highlights the importance of informing our patients about captioning and encouraging its use when they are required to communicate with talkers using face masks. Individuals who specified using a live captioning app during in-person communication exchanges were nearly all hearing aid users (32 of 33 respondents). The two most commonly mentioned captioning apps were Otter App (iOS) and Live Transcribe (Google). Some comments mentioned the fact that captioning apps are not always perfect at voice-to-text conversion. That said, many of our respondents indicated that they find captioning apps to be helpful when communicating with someone who is using a face mask.

Also worth noting are the open-ended responses regarding safety. Middle-age and older participants were more inclined to ask their communication partner to remove their mask, as compared with younger participants. Respondents of all ages reported that they resort to moving closer to the talker. These findings suggest that people who experience difficulty hearing and communicating with talkers wearing a face mask are willing to go against the Centers for Disease Control and Prevention guidelines in order to help improve communication. Both findings are concerning, especially since older adults are at a higher risk of developing complications related to COVID-19. Despite the increased risk, some states with mask mandates acknowledge that modifications to mask rules may be appropriate to maintain compliance with the Americans with Disabilities Act and reasonable accommodations. For example, in Massachusetts, conversing with a person with hearing impairment is an approved exception in the governor's order requiring face coverings (Commonwealth of Massachusetts, 2020).

There are several limitations to this study that suggest that our results should be interpreted with caution. People with hearing loss and hearing aid users were intentionally oversampled. Although we did find statistically significant effects of age group and statistically significant interactions, the effect sizes were not large, and so the extent of differences found between groups may not be meaningful in terms of real-life application. The nature of the way the questions were asked could have biased participants' responses—it was obvious that the researchers anticipated that respondents might have difficulty communicating in noise and/or with face masks, and this could have influenced the way individuals responded. Finally, the lack of objective hearing threshold data restricts what we can say about associations between responses and degree of hearing loss.

Conclusions

Adult respondents of all ages report challenges understanding speech and increased concentration needed to understand speech, when communicating with someone who is using a face mask. These problems are especially notable when conversation takes place in a noisy environment. Even younger adults with self-rated good hearing are not immune to these problems. Among respondents with self-rated *poorer* hearing, middle-age adults indicate experiencing more substantial problems understanding speech in these conditions, as compared with older individuals. Audiologists should discourage the use of strategies that risk the health and safety of individuals (e.g., removing face masks or moving closer) and promote other strategies that our respondents indicate are useful (e.g., using clear masks, translation apps, and active repair strategies).

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Concentration Ratings for All Participants (Figure A1), Participants With Self-Assessed *Better* Hearing (Figure A2), and Participants With Self-Assessed *Poorer* Hearing (Figure A3).

Figure A1. Mean ratings for prompts from all respondents regarding how much they need to concentrate to understand speech in a quiet place (Q) and in a noisy place (N) when the other person is (mask) or is not (no mask) using a face covering. The scale that the participants used for these prompts was bounded by *I need to concentrate very little* (1) to *I need to concentrate a lot* (5). Error bars represent the standard error.

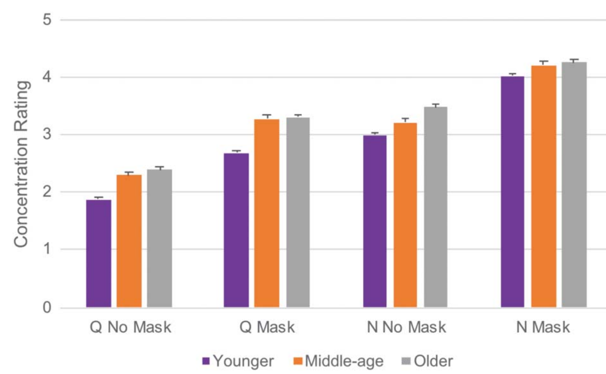
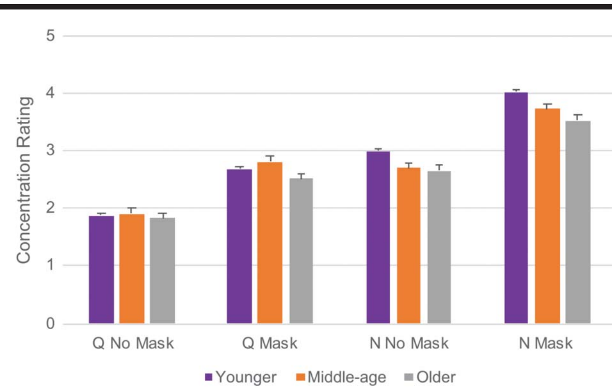


Figure A2. Mean ratings for prompts from respondents who self-rated their hearing as “Excellent” or “Good” regarding how much they need to concentrate to understand speech in a quiet place (Q) and in a noisy place (N) when the other person is (mask) or is not (no mask) using a face covering. The scale that the participants used for these prompts was bounded by *I need to concentrate very little* (1) to *I need to concentrate a lot* (5). Error bars represent the standard error.



Appendix (p. 2 of 2)

Concentration Ratings for All Participants (Figure A1), Participants With Self-Assessed *Better* Hearing (Figure A2), and Participants With Self-Assessed *Poorer* Hearing (Figure A3).

Figure A3. Mean ratings for prompts from respondents who self-rated their hearing as "Fair" or "Poor," aggregated by age category and by hearing aid/cochlear implant use (users vs. nonusers) regarding how much they need to concentrate to understand speech in a quiet place (Q) and in a noisy place (N) when the other person is (mask) or is not (no mask) using a face covering. The scale that the participants used for these prompts was bounded by *I need to concentrate very little* (1) to *I need to concentrate a lot* (5). Error bars represent the standard error.