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ORIGINAL ARTICLE

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A comparison of the impact of the COVID-19 pandemic on communication among individuals with and without hearing impairment

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ABSTRACT

Objective: This study assessed the impact of coronavirus disease-2019 (COVID-19) preventative measures on hearing and communication among individuals with normal and impaired hearing. We also evaluated the use of digital communication tools between these groups.

Design: For this cross-sectional study, participants completed an online digits-in-noise test and survey. Survey topics included understanding through masks, behind plastic screens, from a 1.5-m distance, and use of social network sites/apps, direct messaging, and video calling. Logistic regressions assessed the odds of disagreeing versus agreeing with survey statements.

Study Sample: A total of 880 adults from the National Longitudinal Study on Hearing completed a survey and hearing test. Based on speech reception threshold scores, participants were categorised into "good" (reference group for all analyses), "insufficient", or "poor" hearing groups.

Results: Those with insufficient and poor hearing had more difficulty understanding others through facemasks, plastic screens, and from 1.5 m. Those with poor hearing had a higher odds of video calling more to contact family/friends/acquaintances during the pandemic, but also had more difficulty hearing sufficiently through video calls.

Conclusions: This study addresses methodological weaknesses in previous studies. Results strengthen current evidence of the burden COVID-19 measures place on individuals with hearing impairment.

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Hearing impairment; communication; COVID-19; facemasks; social distancing

Introduction

Wearing facemasks and social distancing during the coronavirus disease-2019 (COVID-19) pandemic have fundamentally changed the way we interact with one another. While many individuals are adaptable to these changes, they may pose additional challenges for the 432 million adults who suffer from hearing loss globally (World Health Organisation [WHO] 2021). As of 2020, approximately one in eight individuals aged 40 years and older has a pure tone average loss of ≥35 decibels (dB) in the Netherlands (Van der Meijden et al. 2020). Given that the pandemic is still ongoing and is expected to persist, a deeper understanding of the impact of the COVID-19 preventative measures on the hearing and communication abilities of individuals with hearing impairment is needed.

Evidence has shown that wearing facemasks and/or distancing is associated with disrupted hearing and communication in everyday life as well as quality of life, overall health, and psychosocial functioning among the general population (Kastendieck et al 2022; Malzanni et al. 2021; Oosthuizen et al. 2022; Saunders et al. 2021). This negative impact on communication may be further exacerbated among individuals with hearing impairment. When comparing those with and without hearing impairment, studies have found that those with more impairment reported greater difficulties with hearing through facemasks as well as with lip-reading (Atcherson et al 2017; Gaeta 2020; Kataoka et al. 2021). Similarly, Saunders et al. (2021) found that facemasks negatively affected hearing, understanding, engagement, and feelings of interpersonal connection, particularly among individuals with hearing impairment compared to those without. While raising volume can help, speech intelligibility remains poorer while wearing masks as they conceal facial expressions and lip patterns necessary for lip-reading and effective interpersonal communication (Hampton et al. 2020; Saunders et al. 2021). Furthermore, studies have also examined how communication from a safe distance differs between those with and without hearing impairment. Kataoka et al. (2021) compared the impact of physical distancing on communication ability between individuals with normal hearing, unilateral, and bilateral hearing loss and found significant differences between these groups, with additional differences found between the different degrees of bilateral hearing loss (ranging from mild to severe). Interestingly, Naylor et al. (2020) did not find differences between participants with "worse" and "better" hearing on their ability to hear others well enough from

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a safe distance, although individuals with "worse" hearing did feel relieved that they were no longer obligated to attend social events where hearing may be challenging. This may imply that in some instances, social isolation or distancing can result in a more controlled and relaxing listening environment, benefitting individuals with hearing impairment (Dunn et al. 2021).

While many studies have investigated transmission of sound via different types of masks or impact of masks on speech understanding within clinical settings (Bandaru et al. 2020; Eddy 2021; Ferrari et al. 2021; Grote et al. 2021; Hampton et al. 2020; Hayirli et al. 2021; Homans and Vroegop, 2021; Ritter et al. 2021), to our knowledge, fewer studies have examined everyday hearing and communication through facemasks, from a safe distance, and behind plastic screens between those with and without hearing impairment. In many of these studies, some uncertainty remains due to the methodology applied. Many did not control for between-participant factors (e.g., education level, employment, age, gender, morbidity), which could influence an individual's perception of and experiences with COVID-19 preventative measures (Gaeta 2020; Naylor et al. 2020, Saunders et al. 2021; Kataoka et al. 2021). Moreover, numerous studies used self-reported hearing to determine hearing status (Gaeta 2020; Naylor et al. 2020; Saunders et al. 2021), while fewer have used objective hearing measures (Kataoka et al. 2021). To our knowledge, no studies have utilised speech-in-noise tests to determine hearing status in the context of COVID-19 preventative measures, despite it being a more objective measure than self-reported hearing (Kramer et al. 1998). It also better reflects an individuals' everyday hearing ability for understanding speech than pure-tone audiometry, as speech understanding is the most important problem for individuals with hearing impairment (Kramer et al. 1998). This makes understanding of speech-in-noise an important measure for research on how COVID-19 preventative measures impact hearing and communication.

Before the pandemic, Van Wier et al. (2021) found that those with hearing impairment were more likely to use social media to connect with family/friends and for work purposes, compared to those with normal hearing. Due to the COVID-19 preventative measures, many individuals increasingly rely on digital tools for communication. Given the hearing and communication difficulties experienced by those with hearing impairment in the context of these measures, we speculate that this group may especially rely on digital communication to facilitate interactions with others during the pandemic. However, research in this area is limited and current findings are mixed. When comparing difficulty with online listening and communication during web classes and meetings during the pandemic, Kataoka et al. (2021) found no significant differences between patients with normal hearing, unilateral, and bilateral hearing loss. Nevertheless, small sample size and confounding factors such as differences in age may have driven this result (e.g., younger individuals may have fewer difficulties solving technological problems). Contrarily, Naylor et al. (2020) demonstrated that those with worse hearing hear more poorly through video calls compared to speaking to another person within the same room, with the former group regarding video calls as being less enjoyable than those with better hearing. Similarly, Saunders and Oliver (2022) found that those with hearing loss viewed telemedicine less positively and preferred in-person care, citing reasons such as mishearing or misunderstanding critical information during online appointments. Among individuals with normal hearing and hearing impairment alike, video calls require more focussed attention to words and less so to non-verbal cues, requiring more listening effort (Sklar 2020). For those with hearing impairment, poor audiovisual quality could make understanding more challenging (Sklar 2020; Tagupa 2020). For this reason, it is of interest to assess how the pandemic has affected not just interpersonal but also virtual communication and identify the challenges pertaining to virtual communication for individuals with hearing impairment. Thus far, no studies have assessed how the use of other types of digital communication in addition to video calling (i.e., social media and direct messaging) may differ between those with and without hearing impairment during the pandemic. Further investigation into these topics is therefore warranted as it could facilitate the development of improvements in interpersonal and virtual communication strategies and ultimately help individuals with hearing disabilities feel more connected in an increasingly (physically) disconnected world.

The present study aims to compare the differences in ability to understand others through facemasks, from a 1.5 m distance, and behind plastic screens among individuals with normal hearing and different levels of speech recognition in noise. It also aims to compare the frequency and increase in use of social media sites/apps, direct messaging, and video calling between these groups.

Materials and methods

Study design and setting

For this cross-sectional study, participants were requested to complete both an online survey and hearing test between November 20th and December 20th, 2020, in the Netherlands. Approximately a month prior to and during the time of data collection, the Netherlands underwent a partial lockdown, with schools, sport centres, and retail stores still open but food/drinks establishments closed. Individuals who could work from home were requested to do so. Social distancing of 1.5 m and wearing facemasks in public transport were mandatory, but in-person events were discouraged. After December 1st, facemasks became mandatory within all closed facilities/areas.

Sample population

Participants were recruited from the Netherlands Longitudinal Study on Hearing (NL-SH), a prospective cohort study beginning in 2006 that aims to examine the relationship between hearing ability and overall health, psychosocial health, healthcare utilisation, and employment. Both adults with normal hearing and hearing impairment aged between 18 and 70 years at time of inclusion into the NL-SH study could enrol for the present study. No other inclusion or exclusion criteria were set. More details regarding the NL-SH can be found in Stam et al. (2015).

On November 20, 2020, 1965 NL-SH participants received email invitations to participate in an extra measurement round for the present study. Via their personal link to the survey, participants were requested to provide informed consent prior to beginning the survey. Participants were excluded from data analysis if they did not provide consent for participation, if they provided consent but did not answer any further questions within the survey, or if they did not complete the hearing test and did not have a prior diagnosis of hearing loss. The NL-SH study protocol has been approved by the IRB (Medical Ethics Committee [METC]) of the Amsterdam Medical Centre, location Vrije Universiteit medisch centrum in Amsterdam, The Netherlands (METC number 2006/83; NL12015.029.06).

Materials

National hearing test

Speech recognition-in-noise was measured via the National Hearing Test (NHT), an online adaptive speech-in-noise test that measures the ability to understand 23 digit-triplets against a background of noise (Smits et al. 2006). The test determines a signal-to-noise ratio (SNR) that corresponds to 50% intelligibility. A 2.5 dB increase of SNR corresponds to an approximately 45% decrease in sentence intelligibility (Smoorenburg 1992). The test correlates highly with thresholds in the pure-tone audiogram (PTA): $r = 0.73$ for $PTA_{(0.5,1,2)}$ and $r = 0.77$ for $PTA_{(0.5,1,2,4)}$ (Smits et al. 2006). The test can be done on a computer, tablet, or smartphone. Participants with hearing aids were instructed to remove their aids to complete the test. We followed the standard procedure for scoring the participants' speech reception threshold (SRT) scores (Smits et al. 2006). These scores determined whether they were categorised into one of three hearing groups which were defined and labelled by Smits et al. as follows: "good" (SRT $<$-5.5 dB SNR), "insufficient" (-5.5 dB SNR $\leq$ SRT $\leq$ -2.8 dB SNR), or "poor" (SRT $>$ -2.8 dB SNR) hearing. Participants who reported having a prior diagnosis of hearing loss (see Table S1 in Supplementary Material, item 28). but were not able to complete the hearing test due to their hearing impairment being profound ($n = 65$) were included in the group with poor hearing.

Survey

Development. The second author drafted the first version of the survey using the research questions of interest as basis for initial development. Topics on understanding ability, use of digital communication tools, general health, and sociodemographic factors were included. Selected items from the NL-SH questionnaire, items based on the survey by Naylor et al. (2020), and our own originally developed items were assembled. An English-to-Dutch translation of items from the survey from Naylor et al. (2020) was developed, followed by the fourth author and colleagues (researchers with backgrounds in questionnaire development) performing three stages of review rounds to evaluate and approve the survey. To assess survey clarity and respondent burden, the survey was pilot tested on a group of colleagues who had no current or prior involvement in this study. The survey for the current study was built in Survalyzer (survey software, version: Survalyzer Classic; https://www.survalyzer.com/) and reviewed for functionality before distribution to participants via e-mail. It consisted of twenty-eight items. A list of these items, their answer options, and original sources can be found in Table S1 in Supplementary Material.

Measures

Understanding ability

Our first aim was to investigate how participants with good, insufficient, and poor hearing differ in their *ability to understand others sufficiently through facemasks*, *from a 1.5 m distance,* and *behind plastic screens*. Participants were asked to rate their level of agreement to three statements using a 4-point Likert scale ranging from "fully disagree" to "fully agree". A "neutral" response was omitted as it was deemed inapplicable to some statements and to encourage participants to choose a response. Two of the three statements were based on Naylor et al. (2020), while the other was originally developed (see Table S1 in Supplementary Material, items 1–3).

Digital communication tools

Our second aim was to investigate how participants with good, insufficient, and poor hearing differ in their use of social network site/apps, direct messaging, and video calling. Use was further specified as *using the digital tool at all* (answer options "yes" or "no"), the *frequency of its use* ("never", "monthly", "weekly", "daily"), and *whether an increase in its use during the COVID-19 pandemic was experienced* ("fully disagree" to "fully agree"). Use of direct messaging and video calling may differ for work and private purposes, for that reason these were studied separately. Furthermore, to gain insight into communication difficulties during video calls, which could affect their use, participants were asked to rate their level of agreement with statements regarding their *understanding ability through video calls* and *enjoyment of group video calls* ("fully disagree" to "fully agree"). A mix of questions and statements was used, based on Naylor et al. (2020) as well as originally developed. A list of these survey items, their answer options, and original sources can be found in Table S1 in Supplementary Material (items 4–19).

Sociodemographic information

Remaining questions in the survey regarded participants' *age, sex, hearing aid* or *cochlear implant use*, *prior diagnosis of hearing loss, level of education, employment status, living status,* and *self-reported health status.* A list of survey items for sociodemographic and potential confounding variables, their answer options, and original sources can be found in Table S1 in Supplementary Material (items 20–28).

All items except for *hearing aid/cochlear implant use* and *prior diagnosis of hearing loss* were examined for potential confounding effects on the association between hearing ability, the ability to understand others through masks, screens, and from a 1.5 m distance, and patterns of use of different digital communication tools, which might be influenced by age, sex, education level, health status, and living situation. Hearing loss severity has been shown to be associated with male sex (Pearson et al. 1995), age, lower education, and more chronic health problems (Dalton et al. 2003). We inferred that these above-mentioned variables might confound our main effects.

Statistical analysis

Univariate and multivariate analyses provided descriptive statistics for the total sample population and by SRT group. Frequencies (with percentages), means (M), medians (interquartile ranges), and standard deviations (SD) were reported for sociodemographic characteristics and hearing-related variables across the total sample and by SRT group.

To assess whether understanding ability and use of digital communication tools significantly differed between SRT groups, we conducted binary logistic regressions (BLR) and multinomial logistic regressions (MLRs). For items whose responses ranged on a 4-point Likert scale, the "fully agree" and "agree" categories were merged and "fully disagree" and "disagree" categories were merged for BLRs in order to retain simplicity and understandability of results. For items whose responses ranged from "never" to "daily", MLRs were conducted. Each item statement was analysed separately. The main independent variable of interest was hearing ability.

Linearity, multicollinearity, and outliers were tested for eligibility for BLRs and MLRs for all dependent variables. For all dependent variables, BLRs and MLRs were conducted for both crude and adjusted models. Odds ratios with 95% confidence intervals were used to estimate statistical significance of all outcomes.

Sensitivity analyses were performed using MLR to assess whether data loss from dichotomisation of the original Likert agreement scale could have resulted in divergent results compared to the original scale. MLR results can be found in Tables S7–S9 in Supplementary Material. For all regressions, the group with good hearing was used as the reference group. All analyses were conducted using IBM SPSS Statistics 26.

Results

Response rate

A total of $n=880$ (44.8%) of the $N=1965$ invited participants completed both the NHT and survey. Out of those invited, $n=1014$ (51.6%) gave no response and $n=45$ (2.3%) provided informed consent but no other data.

Sample characteristics

Descriptive statistics for sociodemographic data are shown in Table 1. Median (interquartile range) of age of participants was 64.5 (55.3, 70.5) and over half were female. Over half of all participants completed a high level of education and did not live in a household alone. Less than half of all participants indicated having a paid job. Over 70% ($n=633$) of all participants indicated having a prior diagnosis of hearing loss. Based on their SRT scores, 38.2% ($n=336$) of participants were categorised as having good hearing, 20.1% ($n=177$) as having insufficient hearing, and 41.7% ($n=367$) as having poor hearing ability.

Understanding ability

Understanding through masks

Participants were asked to rate their level of agreement on their ability to understand others sufficiently through facemasks (see Table S2 in Supplementary Material, item 1). After adjusting for confounders, BLR showed that individuals with insufficient (OR = 2.84 (95% CI [1.92, 4.20])) and poor hearing (OR = 15 (95% CI [10.0, 23.1])) had a significantly higher odds of disagreeing with the statement that they understand others sufficiently through facemasks, compared to individuals with good hearing.

Understanding behind plastic screens

Participants were asked to rate their level of agreement on their ability to understand others sufficiently behind a plastic screen (Table S2 in Supplementary Material, item 2). After adjusting for confounders, those with insufficient (OR = 1.88 (95% CI [1.25, 2.82])) and poor hearing (OR = 5.23 (95% CI [3.71, 7.38])) had a significantly higher odds of disagreeing with the statement that they understand others sufficiently from behind a plastic screen, compared to those with good hearing.

Understanding from a 1.5 m distance

Participants were asked to rate their level of agreement on their ability to understand others sufficiently from a 1.5 m distance (Table S2 in Supplementary Material, item 3). After adjusting for confounders, individuals with insufficient (OR = 3.28 (95% CI [2.03, 5.30])) and poor hearing (OR = 11 (95% CI [7.51, 17.1]))

Table 1. Descriptive statistics for demographic variables by total sample and hearing ability.

			Hearing ability		
Demographic information		Total sample (*N* 880) *M* (SD) or *n* (%)	Good (*n* 336) *M* (SD) or *n* (%)	Insufficient (*n* 177) *M* (SD) or *n* (%)	Poor (*n* 367) M (SD) or *n* (%)
Age (years)[a]	*n*	64.5 (55.3, 70.5)	61.8 (67.8, 51.5)	65.4 (58.7, 70.5)	66.4 (59.0, 72.1)
		880	336	177	367
Sex	Female	505 (57.4)	184 (54.8)	100 (56.5)	221 (60.2)
	n	880	336	177	367
Prior diagnosis of hearing loss	Yes	633 (71.9)	143 (42.6)	134 (75.7)	356 (97.0)
	n	880	336	177	367
Hearing aid users	Yes	442 (69.8)	43 (30.1)	90 (67.2)	309 (86.8)
	n	633	143	134	356
Cochlear implant users	Yes	43 (6.8)	1 (0.7)	1 (0.7)	41 (11.5)
	n	633	143	134	356
Education	Low	117 (13.5)	31 (9.3)	28 (16.0)	58 (16.1)
	Medium	219 (25.2)	77 (23.1)	41 (23.4)	101 (28.1)
	High	533 (61.3)	226 (67.7)	106 (60.6)	201 (55.8)
	n	869	334	175	360
Employment	Paid job	358 (41.2)	181 (54.2)	69 (39.4)	108 (30.0)
	Retired	332 (38.2)	100 (29.9)	71 (40.6)	161 (44.7)
	Other	179 (20.6)	53 (15.9)	35 (20.0)	91 (25.3)
	N	869	334	175	360
Health status	(0– 100)	72.8 (21.8)	75.3 (19.1)	70.6 (24.4)	71.5 (22.6)
	N	877	335	176	366
Living situation	Alone	198 (23.4)	80 (24.6)	34 (20.2)	84 (23.9)
	n	845	325	168	352

M: mean; SD: standard deviation; *N*: total sample size; *n*: subgroup sample size; IQR: interquartile range

Data may be missing in some of the non-mandatory survey items; therefore, subgroup sample sizes are presented. For example, only those with a prior diagnosis of hearing loss ($n=633$) were asked to report whether they use hearing aids or a cochlear implant. Hence, the sample size for hearing aid users and cochlear implant users is $n=633$.

[a]Median (interquartile range) are shown.

had a significantly higher odds of disagreeing with the statement that they understand others sufficiently from a 1.5 m distance, compared to those with good hearing.

Digital communication tools

Use of digital communication tools

Participants were asked to indicate whether they use the three digital communication tools at all. After adjusting for confounders, no statistically significant differences were found in social network sites/apps nor direct messaging use between the three SRT groups (see Table S3 in Supplementary Material, items 4-5). Those with poor hearing had a statistically significant lower odds (OR = 0.56 (95% CI [0.38, 0.83]) of using internet programs or apps for video calling compared to those with good hearing (item 6). No significant differences in use of video calling between those with insufficient and good hearing were found.

Frequency of use to contact family/friends/acquaintances

Participants were asked to rate their current frequency of use of social network sites/apps, direct messaging, and video calling to contact friends/family/acquaintances. After adjusting for confounders, no statistically significant differences were found in frequency of social network site/app use, direct messaging, or video calling between the three SRT groups (Table S4 in Supplementary Material, items 7-9).

Frequency of use for work purposes

Participants were asked to rate their frequency of direct messaging for work purposes (see Table S4 in Supplementary Material, item 10). After adjusting for confounders, those with insufficient but not poor hearing had a statistically significant higher odds of direct messaging (OR = 5.16 (95% CI [1.42, 18.8]) monthly, compared to those with good hearing. No significant differences in video calling were found between the three SRT groups (item 11).

Increase in use of digital communication tools during the pandemic compared to before

Participants were asked to indicate whether they increased their use of social network sites/apps, direct messaging, and video calling to keep in touch with friends/family/acquaintances since the start of the COVID-19 pandemic. After adjusting for confounders, no significant differences were found between SRT groups in whether they increased their use of social network sites/apps nor in direct messaging to keep in touch with friends/family/acquaintances (see Table S5 in Supplementary Material, items 12-13). After adjusting for confounders, those with poor hearing had a higher odds having increased video calling to keep in touch with friends/family/acquaintances, compared to those with good hearing (OR = 1.89 (95% CI [1.24, 2.90])). No significant differences in video calling were found between those with insufficient and good hearing (item 14). After adjusting for confounders, no significant differences were found between SRT groups on whether they increased their use of direct messaging and video calling for work purposes (items 15-16).

Understanding ability through video calls

Participants were asked to indicate whether they were able to hear another person through video calls just as well as if they were speaking with another within the same room (see Table S6 in Supplementary Material, item 17) and via the telephone (item 18). Individuals with insufficient (OR = 2.03 (95% CI [1.30, 3.17])) and poor hearing (OR = 3.93 (95% CI [2.66, 5.82])) had a statistically significant higher odds of not hearing another person through video calls as well as speaking in the same room, compared to those with good hearing. Individuals with insufficient (OR = 2.03 (95% CI [1.27, 3.26])) and poor hearing (OR = 5.27 (95% CI [3.51, 7.93])) had a statistically significant higher odds of having difficulty hearing another person through video calls as well as via the telephone, compared to those with good hearing. No significant differences were found between individuals with insufficient and good hearing in whether they find group video calls (with two or more people) enjoyable (item 19). Individuals with poor hearing did have a statistically significant higher odds of disagreeing with the statement that they find group video calls enjoyable, compared to those with good hearing (OR = 2.82, 95% CI [1.89, 4.20])).

Sensitivity analyses

Results of the sensitivity analyses are shown in Tables S7–S9 in Supplementary Material. The reference group in these analyses consists of participants who fully agree with a statement. Most results were similar to the dichotomous results, apart from three differences. In Table S8 in Supplementary Material (items 1 and 2), those with poor hearing had a lower odds of using social network sites (OR = 0.42, 95% CI [0.19, 0.92]) and direct messaging (OR = 0.51, 95% CI [0.27, 0.98]) to contact family/friends/acquaintances more often now than before the pandemic. For item 5 in this table, those with poor hearing had a higher odds of simply "agreeing" with the statement that they video call for work more often now compared to before the pandemic (OR = 2.30, 95% CI [1.19, 4.45]).

Discussion

Interpretation of findings

The present study aimed to investigate the communication and hearing-related difficulties experienced among individuals with different levels of speech recognition-in-noise during the COVID-19 pandemic. We also investigated the use of digital communication tools among the three groups. Results showed that individuals with poor and insufficient hearing have more difficulty understanding others sufficiently through masks, behind plastic screens, and from a 1.5 m distance, compared to those with good hearing. While over half of all participants reported increasing video calling friends/family/acquaintances during the pandemic, those with poor and insufficient hearing struggle more greatly with understanding others sufficiently during video calls compared to those with good hearing. Individuals with poor hearing also find group video calls significantly less enjoyable, possibly due to challenges related to audiovisual quality of video calls.

Our results that individuals with poor hearing have greater difficulty understanding others through masks, plastic screens, and from 1.5 m distance, in everyday life, are in agreement with prior research (Gaeta 2020; Kataoka et al. 2021; Naylor et al. 2020; Saunders et al. 2021). This is expected as research has shown the reduction in sound intensity, audibility and speech intelligibility that can result from speaking while wearing masks and/or from a distance (Atcherson et al. 2017; Eddy 2021;

Hampton et al. 2020; Homans & Vroegop 2021; Muzzi et al. 2021). Our findings highlight the need to provide extra support to individuals with poorer when these protective measures are used.

While those with poor hearing were less likely to video call at all, most participants regardless of hearing ability reported increasing their video calling to stay in touch with friends/family/acquaintances during the pandemic. Contrary to Naylor et al. (2020), our study did find that those with poor hearing were significantly more likely to state they increased video calling with friends/family/acquaintances than those with good hearing, which may reflect the way social interactions have changed as a result of the pandemic's mandates (i.e., requiring reduced in-person contact) and how it has changed particularly for those with hearing loss. Those with poor hearing may avoid in-person communication in favour of video calling, during which one can adjust the volume of calls or stream calls to hearing aids to facilitate hearing. Another reason could be that video calls allow for a more socially isolated, less stressful listening environment for those with poorer hearing, compared to in-person interactions (Dunn et al. 2021). However, contrary to Kataoka et al. (2021), we found that those with hearing impairment were more likely than those with good hearing to indicate they had difficulty hearing well through video calls and find group video calls unenjoyable, which could be due to poor audiovisual quality that negatively impacts the ability to see visual cues and expressions needed for lip-reading. Seeing this, video calling may pose as a necessity rather than a preference to keep in touch with others for those with hearing impairment and highlights the need to optimise digital communication technologies or develop creative alternatives for improved in-person and virtual communication for these individuals.

No significant differences between those with good, insufficient, and poor hearing were found in frequency of video calling for work. Yet, more than half of all individuals indicated video calling more for work during the pandemic compared to before, but no differences between SRT groups were found either. This could reflect a larger change in social interactions across all individuals regardless of hearing ability. Individuals with poorer hearing may more likely be unfit for work, looking for employment, or not working full-time (Stam et al. 2013), which could have also impacted these results as fewer individuals were able to provide this data.

To our knowledge, our study is the first to assess the impact of other digital communication technologies (besides video calling), such as social network site/app and direct messaging use, on communication among those with good, insufficient, and poor hearing during the COVID-19 pandemic. Regardless of hearing ability, most participants utilise social network sites/apps on a daily basis. Since no group differences were found in use at all, frequency, nor in increase in use, however, this may indicate that the pandemic itself did not affect social network use for directly communicating with others. Perhaps its primary use is for sharing and viewing personal content, rather than as a means of direct communication with one or more individuals.

While over half of all participants direct message friends/family/acquaintances daily and direct message them more often during the pandemic, no significant differences between SRT groups were found. Again, this could reflect changes in social interactions due to the pandemic and the popularity that direct messaging is for contacting others, regardless of hearing ability. When evaluating current frequency of direct messaging for work, results are not easily understood. Over 70% of working-individuals from all three SRT groups reported direct messaging for work on at least a weekly basis, which reflects a popularity or acceptance for this communication method for this purpose. Compared to individuals with good hearing, those with insufficient hearing did indicate direct messaging for work less frequently (monthly compared to daily), which may reflect a different nature of work and/or work demands for this group rather than related to hearing ability (e.g., perhaps email communication was preferred during this time). The lack of group differences in whether participants increased direct messaging for work during the pandemic may also reveal that those with and without hearing impairment may not see it as an asset or more valuable for use for work purposes during the pandemic compared to before.

Results from the main (dichotomous) and sensitivity (multinomial) analyses of agreement with statements coincided, apart from three items. While dichotomous results revealed no differences between SRT groups on these statements, multinomial results showed that those with poor hearing were more likely to agree that they (i) use social network sites and (ii) direct messaging to contact family/friends/acquaintances, as well as (iii) that they video call for work more often now than before the pandemic (albeit still less than individuals with good hearing). These analyses may have revealed the existence subgroups of individuals with more severe hearing loss who scored on one negative extreme of the Likert scale responses compared to those with normal hearing. More research on these subgroups may further reveal the hardships faced by those with severe hearing loss.

Strengths and limitations

There are several strengths of the current study. To our knowledge, our study contains the largest sample to date for this research topic. Compared to existing studies, our study evaluates a broader range of topics from understanding ability to use of three types of digital communication tools. Our large sample size and broad range of questions adds to the novelty of this study and facilitated in providing a higher statistical power.

While we found statistically significant odds ratios for some of our outcome variables, a limiting factor was that some of their confidence intervals were very wide, which may arise due to differential interpretations of the survey items and/or response choices, the context in which the survey was completed, or unknown residual confounding not accounted for in our study. Residual confounding from visual impairment and cognition could have played a role in obscuring the actual level of communication difficulties that individuals with hearing impairment reported. No measures were taken to reduce or correct for response biases, like choosing the first response option or tending to agree with the presented statements. Additionally, omitting a "neutral" answer option for some of the item statements could have forced participants to choose to agree or disagree and consequently not accurately reflect their true responses in some cases. Participants may have also completed the survey at a different time, with some doing so a couple of weeks prior to stricter lockdown measures instated by the Dutch government and others during this period. This in turn can result in a wider effect estimate, thereby affecting confidence intervals. Although we have no doubt large differences exist between the hearing groups, it is important to bear in mind that equal levels of hearing impairment can cause variable amounts of disability among different individuals, making communication and hearing disabilities not always predictable from the severity of one's SRT score (Rouhbakhsh et al. 2007). Furthermore, we did not adjust our p-values for multiple testing since our study is exploratory by design and therefore refrained from being too strict in setting the significance level or correcting for multiple testing.

Possible misclassification of SRT group for some individuals cannot be ruled out. Eight individuals reported having a prior diagnosis of hearing loss from their physician, but their NHT results placed them into the group with good hearing. While we hypothesise this could likely be due to some having conductive hearing loss, these participants may have been rightfully placed into this group if they conducted the hearing test with volume high enough (which may mimic natural conditions). Similarly, 43 hearing aid users and 1 cochlear implant user who scored well on the NHT were placed in the "good hearing" group. These individuals may have disregarded instructions to remove their hearing aids before performing the hearing test, resulting in slightly better scores, or may have scored just above the cut-off between the "good" and "insufficient" categorizations. Nevertheless, the NHT is known to be fairly unaffected by changes in environment, equipment, or absolute presentation level (Smits et al. 2004; Smoorenburg 1992).

Another limitation of our study could be a healthy volunteer effect within our sample. Although approximately 72% of participants reported having a hearing disability, more than half were highly educated, had a high digital health literacy, and good self-reported health status. Given that our participants represent a larger willingness to participate in online scientific research, they may be more health-conscious, tech-savvy and more likely to utilise digital tools more frequently compared to the general population. They may also suffer from poorer hearing and be more willing to share or complain about the challenges faced during the pandemic, as we see a higher proportion of NL-SH participants with hearing problems among those taking part in the COVID-19 survey than in the full NL-SH sample (Goderie et al. 2020). This, with a period of months of increased tension and politicisation of the pandemic, may have affected their experiences or attitudes towards the COVID-19 measures and willingness to participate in our study. Indeed, 53.9% of the original NL-SH sample chose not to participate in the COVID-19 survey. This could make our results less generalisable to a larger population of individuals with hearing impairment. Conversely, perhaps our sample is better at finding solutions to technological problems, albeit still not finding video calls enjoyable and preferring in-person interactions, and overcome communication challenges by taking advantage of solutions such as speaking loudly or using transcription apps earlier on in the pandemic. It is important to note that the difficulties with understanding others sufficiently through masks, etc. are not limited to only those with poor hearing, which could attenuate our odds ratios. Finally, the complete survey was not tested for reliability and validity due to lack of time available for testing and uncertainty of how long the pandemic would persist at the time.

Conclusion

People with poor and insufficient hearing have considerably more difficulty understanding others through masks, plastic screens, and from a 1.5 m distance compared to those with good hearing. These results strengthen findings from previous research by addressing some of the weaknesses in this research, namely use of a larger sample, an objective test of speech-in-noise understanding, and taking differences in age, sex, education level, living situation, and health status into account. Given the disproportionate impact of the pandemic on individuals with hearing disabilities, additional research examining the extent to the which these communication difficulties impact the psychosocial health of individuals with poor and insufficient hearing is warranted.

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Data availability statement

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

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