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Impact of face masks on communication in the D/deaf/Hard of Hearing (HOH) younger and middle adults during COVID-19 pandemic: A systematic review

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INTRODUCTION

The COVID-19 pandemic has created chaos in the world. The World Health Organization (WHO) states that Corona virus disease (COVID-19) is an infectious disease caused by the SARS-CoV-2 virus (Severe Acute Respiratory Syndrome Corona virus-2) that emerged in Wuhan, China on December 2019. The COVID-19 spreads from one person to another and can be diagnosed with a laboratory test and it affects different people in different ways like serious illness or death at any age. The symptoms seen are difficulty breathing or shortness of breath, loss of speech or mobility or confusion, chest pain, fever, cough, tiredne and loss of taste or smell whereas the fewer symptoms are sore throat, headache, diarrhoea, red or irritated eyes and rash on skin and discolourations of fingers or toes. COVID-19 can be prevented by getting vaccine doses, maintaining social distancing, wearing the face masks, hand hygiene (washing hands with soaps, spirits or sanitizers), staying away from others and self isolation at home or hospital if felt sick until recovery and covering mouth and nose when coughing or sneezing.

Universal Medical and Centers for Disease Control and Prevention (CDC) (2020) states that the face masks are simple barriers which will help to prevent the spread of infection (COVID-19) and the face masks are part of an infection control strategy to eliminate cross contamination. So, wearing face masks are important and help us to protect ourselves and those around us. The clear transparent face masks or cloth masks with a clear plastic panel are also available for the people who are deaf or hard of hearing; young children or students learning to read; students learning a new language; people with disabilities and people who need to see the proper shape of the mouth for making appropriate vowel sounds. The face mask reduces the volume and clarity of speech and social distancing and protective barriers make it harder to hear. People who are deaf or hard of hearing may find difficulty in reading lips when people wear face masks and struggle in communication with the hearing people. The communication challenges faced by deaf or hard of hearing people everyday include that they can't lipread, obscuring speech, loneliness and isolation, lack of facial expressions, body language and non-verbal communication.

Many studies have been conducted to check the effect of surgical masks on speech intelligibility in normal hearing individuals (Bandaru et al. 2020; Hampton et al. 2020; Cohn, Pycha, and Zellou 2021; Muzzi et al. 2021; Toscano & Toscano 2021). Atcherson et al. (2017) tested the effect of traditional and transparent masks on speech perception in noise for adults with and without hearing loss. Normal hearing subjects showed no differences in speech perception in noise when visual input was delivered via a transparent surgical mask against a conventional mask, whereas subjects with hearing loss reported improved speech perception in noise when visual input was provided via a transparent surgical mask vs a conventional mask.

Some researchers stated that, "Communicating during COVID-19 pandemic with face mask is already stressful enough; we should not have to worry about being heard" and "Talkers who use clear masks or any masks should consider using sound reinforcement or assistive listening system to improve audibility and reduce vocal fatigue". So, the face masks impeded the communication in people with hearing loss.

Communication

Oxford Dictionary states that Communication is the act of giving, receiving and sharing the information such as talking, writing, reading and listening from one person to another person. In other words, it is the process of exchanging information and ideas through a common system of signs, symbols and behaviours. Communication has both speech and language. Common Sense Media also states that the strong communication skills can help the kids interact both face-to-face and in the online world. The humans need accessible language and so the communication connects us to each other and the communication problem solving requires more effort from everyone involved to experience effective communication.

There are 3 parts to Communication: sender, message and recipient. The sender 'encodes' the message, transmitted in some ways and the recipient 'decodes' it. The good communicators listen carefully, speak or write clearly. This exchange of information can be of 4 types: Verbal Communication, Non-Verbal Communication, Written Communication and Visualizations.

Verbal Communication is the spoken conveyance of a message and information. Non-Verbal Communication is the process of conveying a type of information in the form of non-linguistic representations such as haptic and chronemic communications, gestures and cues, body language, facial expressions and eye contact. Written Communication includes e-mails, social media, and books, magazines, Internet and other media. In the modern world, we can write and publish our ideas online which led to the communication possibilities. Visualizations include graphs and charts, maps, logos and other visualizations can all communicate messages.

Collins Dictionary (2021) states that the Communication breakdown is defined as a failure to exchange information resulting in a lack of communication. Management Study Guide (MSG) states that there are various causes of communication breakdowns such as the lost in translations, poor retention, perceptual and language differences, attention span of a gnat (or) inattention, too much information (or) information overload, time pressures, emotions, distractions/noises and Complexity in Organizational structure. Hearing loss is one of the main causes of communication breakdowns.

Hearing loss and Communication

Oxford Dictionary states that the hearing loss is the total or significant loss of hearing in one or both ears ranging from mild to profound and it occurs at any ages. National Institute on Aging (2020) states that the hearing loss is a common problem caused by noise, aging, disease and heredity. People with hearing loss may find it hard to have conversations with friends and family and they may also have trouble understanding doctor's advice responding to warnings and hearing doorbells and alarms. There are many symptoms and signs and causes of hearing loss. Healthy Hearing states that the 3 types of hearing loss are:

- Conductive hearing loss (involves outer ear and middle ear)
- Sensorineural hearing loss (involves inner ear)
- Mixed hearing loss (involves both conductive and sensorineural)

Centers for Disease Control and Prevention (CDC) (2020) states that the hearing loss can be described as:

- Unilateral or Bilateral (Hearing loss in one ear or both ears)
- Pre-lingual or Post-lingual (Hearing loss happened before a person learned to talk or after a person learned to talk)
- Symmetrical or Asymmetrical (Hearing loss is the same in both ears or different in each ear)
- Progressive or Sudden (Hearing loss worsens over time or happens quickly)
- Fluctuating or Stable (Hearing loss gets either better/worse over time or stays the same over time)
- Congenital or Acquired/Delayed Onset (Hearing loss is present at birth or appears sometime later in life)

Cincinnati Children's foundation (2019) states that the hearing loss can affect child's/adults' development of speech and language skills and so the communication skills are affected. When a child/adult has difficult hearing, the areas of the brain used for communication may not develop properly and so this makes understanding and talking very difficult. When the hearing loss is identified early and managed appropriately with the use of hearing aids/cochlear implants, the child can become an effective communicator. This process involves caregivers, parents and professionals working together and is essential in the diagnosis and intervention process. Most hearing losses are identified through screening at birth itself and so the early identification and the management of hearing loss resulted in better outcomes for the child. Some children are not diagnosed until later, when the speech or language skills are not progressing.

Valli Gideons (2021) states that if a child/adult who has hearing loss does not respond, it is not selective hearing, bad behaviour and just a matter of turning up devices. Listening and living with hearing loss is harder and difficulty than it looks. Hearing loss is complex and so it's exhausting and listening/auditory fatigues and burnouts are real. Patience, awareness and understanding are keys to communication.

When facing the child/adult with hearing impairment, speak clearly, never cover your mouth, try not to turn your back, speak one at a time, remove background noises, avoid saying "Nevermind" because it's hurtful, isolating and rude. We should be patient when facing children/adults with hearing loss. Children/adults who have hearing loss do not need to be fixed. They aren't the broken ones, they are whole and they are both capable and amazing.

Henn et al. (2017) interviewed students who had hearing loss to see if and how their hearing loss affected their medical consultations. Because of their hearing loss, around 60% said they misheard or misconstrued information during a medical appointment. About 20% of people blamed their problems on the doctor's or nurse's communication style, which included mentions of staff wearing masks as a concern.

Classification of age groups

Conduent Healthy Communities Institute (2021) states that the age groups can be classified into:

- → Infants: less than 1 year old(<1)
- → Children: 1-11 years old
- → Teenage (or) Adolescents: 12-18 years old
- → Adults: 18-64 years old
  - ✓ Younger adults: 18-35 years old
  - ✓ Middle adults: 36-64 years old
- → Older Adults (or) Seniors: 65 years old and above (>65)

Understanding among D/deaf/Hard of Hearing (HOH) communities

We need to understand the hearing impaired community. They too prefer to be identified differently. Ai Media (AM) states that the "uppercase D" Deaf is used to describe the people who identify themselves as culturally Deaf. They prefer to use sign languages and on the most occasions, it is their primary source of communication. The Deaf culture is not against the cochlear implants, but includes the people with diverse viewpoints on hearing technologies.

The “lowercase d” deaf is a more general term for people who are physically deaf but do not identify as members of the signing Deaf community and don’t always use sign languages. They usually integrate with and potentially feel comfortable in the hearing world where they prefer to communicate orally.

The people who are Hard of Hearing (HOH) are the people with hearing loss that permit the partial use of the ear to a certain degree. They typically use hearing aids, cochlear implants and FM systems. These people usually communicate via speech-reading, lip-reading and/or residual hearing.

Sometimes, the term Deafblind is used if the people are having problems and difficulty in both vision (blind) and hearing (Deaf). And, the terms Deaf-Dumb/Deaf-Mute and Hearing impaired should never be used. The terms Deaf-Dumb/Deaf-Mute describe the notion that the people with significant hearing loss from birth cannot hear and communicate by any means throughout their lives and they should never be used as they are inappropriate and inaccurate.

The term hearing impaired is much preferred by the hearing people largely because they view it as politically correct but it is technically negative and offensive. To be fair, this is probably not what people intended to convey by the term ‘hearing impaired’ and so it should be avoided.

So the words and labels can have a huge impact on the people. D/deaf/HOH people can be sensitive as to how they are referred to because they have experienced being put down and disparaged by other people. This community has faced a lot of challenges due to the COVID-19 pandemic. Adults who are deaf are more likely to have poor health literacy (McKee, Paasche-Orlow et al., 2015). Health literacy is defined as the ability to find, comprehend, evaluate, and use health information and services to make informed health decisions (Coleman et al., 2008; Ratzan & Parker, 2006).

REVIEW OF LITERATURE

A face mask hides the bottom half of the face, which is especially effective for identifying emotional expressions (Blais et al. 2017; Carbon, 2020) and enhancing communication through lip reading (Rosenblum et al. 1996), especially when there is background noise (Sumby & Pollack, 1954). The few research that have looked at the impact of face masks on communication have found a mask-induced voice attenuation of 2 to 12 dB (Atcherson et al., 2017; Goldin et al., 2020; Mendel et al., 2008) and a benefit of transparent masks in hearing-impaired people (Atcherson et al., 2017). The impact of face masks on speech comprehension was rarely studied in real-life situations, and the impact of concealing the lips (a visual feature) was not separated from the impact of voice distortions (an auditory characteristic) caused by the mask (Llamas et al. 2009). Due to muffled speech and the inability to lip-read, hearing-impaired patients had difficulty understanding healthcare workers wearing face masks (Trecca et al. 2020), while Chodosh et al. (2020) provided an overview of the challenges people with hearing loss faced from a clinical perspective as medical staff are required to wear face masks.

Those who are deaf and hard of hearing (DHH) who have Intellectual Disabilities (ID) frequently have communicative challenges because they live in situations that do not sufficiently support their visual communication needs. Aggressive conduct might be exacerbated by communication obstacles (McClintock, Hall & Oliver, 2003). Communication between healthcare providers and deaf patients is difficult, especially in the midst of the present COVID-19 pandemic. Many sign language interpreters are unable to access hospitals and clinics, interpreting via video relay are not always practicable, and lip-reading is impossible with face masks. Traditional face coverings not only degrade speech quality, but they also provide a visual barrier to facial cues and lip-reading, which is especially problematic for deaf or hard-of-hearing people (Mendel et al., 2008; Atcherson et al., 2017; Chodosh et al., 2020; Atcherson et al., 2020; Tucci, 2020; Eby et al., 2020; Corey et al., 2020). Aside from the lack of facial clues, the speaker's emotions can be affected as well (Tucci, 2020).

Clients and patients receiving speech-language and audiology treatments, another population group with a variety of speech, voice, language, and hearing communication problems, would be impacted by increased mask use, according to Baltimore and Atcherson (2020).

Homans and Vroegop (2021) investigated the effect of surgical masks and face shields on speech intelligibility of adults with moderate to severe hearing loss and measured speech tracking scores in quiet for life speech without surgical mask, surgical mask and face shield. The study sample consisted of 42 patients with moderate to severe hearing loss, 23 Cochlear Implant users and 19 Hearing Aid users. The results indicated that a significant average difference in speech perception scores was found for the use of a surgical mask compared to the listening situation without mask and even the face shield had a negative impact on speech perception. They concluded that even for speech perception in quiet, surgical face masks and face shields to a lesser extent had a negative impact for the patients with moderate to severe hearing loss.

The challenges faced by the deaf and hard of hearing (hearing-impaired) people during COVID-19 by a literature review were assessed by Garg, Deshmukh, Singh, Borle and Wilson (2021) and concluded that the challenges faced were the lack of information, face mask making communication difficult, social distancing affecting their physical, mental health, stigma and barriers related to the health-care system and the system strengthening, tele-medicine, and policy amendments could be the pillars to build up the support system for the hearing impaired to protect them from COVID-19.

Homans and Vroegop (2021) investigated the potential problems in the daily life communication of Cochlear Implant (CI) patients due to the widespread use of face masks in public places during the COVID-19 pandemic was studied and used. An online questionnaire (which consisted of face mask questionnaire, loneliness question and 3 sub-domains of the Nijmegan Cochlear Implant Questionnaire to assess the quality of life) about the effects of face masks on the daily life communication of adult CI users was used. About 407 adult CI users were invited to participate.

The loneliness question and Nijmegan CI Questionnaire were analyzed for the possible differences between the current situation with masks and the situation before when the masks weren't commonly used. The results indicated that 221 adult CI users participated; the face mask questionnaire showed that the face mask caused considerable problems in daily life communication of 80% of the participants and then the CI users tended to feel lonely and all used sub-domains of the Nijmegan CI Questionnaire worsened due to the use of face masks. They concluded that the widespread use of face masks greatly complicated the daily life communication of CI users and reduced the quality of life.

Atcherson, McDowell and Howard (2021) included some newer mask options as well as transparent masks to help deaf or hard of hearing that depended on lip-reading and other facial cues. The results corroborated earlier published results for non-transparent masks but transparent options (masks) had greater attenuation, resonant peaks and deflected sounds that the non-transparent masks didn't. The presence of visual cues remained important for both verbal and non-verbal communication although transparent face coverings had poorer acoustic performance and concluded that there were creative solutions and technologies available to overcome audio and/or visual barriers caused by the face coverings.

The impact of face coverings on hearing and communication was studied by Saunders, Jackson and Visram (2021). An online survey consisting of closed-set and open-ended questions distributed within UK to gain insights into experiences of interactions involving face coverings and of the impact of face coverings on communication. A total of 460 members were recruited via snowball sampling and the people with hearing loss were oversampled to more thoroughly assess the effect of face coverings. The results indicated that the participants reported the face coverings negatively impacted hearing, understanding, engagement and the feelings of connection with the speaker. The people with hearing loss were significantly more impacted than those without hearing loss. The face coverings impacted communication content, interpersonal connectedness and willingness to engage in conversation and increased anxiety and stress, and made communication fatiguing, frustrating and embarrassing.

They concluded that the face-coverings had far-reaching impacts on communication for everyone but especially for people with hearing loss and then the findings illustrated the need for communication-friendly face coverings and emphasized the need to be communication-aware when wearing a face covering.

In a study, Thibodeau, Nielsen, Tran and Jacob (2021) assessed the speech recognition in noise when using a transparent mask that allowed greater visibility of the talker's face compared to an opaque mask in persons with normal and impaired hearing via an online format. A repeated-measures design was used to evaluate the auditory-visual recognition of sentences recorded in background noise with transparent and opaque face masks and without a mask (N=154). The listeners completed the 40-minute online session on computer, laptop or tablet in a quiet room via their personal listening devices and the adult volunteers were recruited through social media links and email and categorized into 3 groups: normal hearing and confirmed or suspected hearing loss either with or without the use of assistive listening devices. The results indicated that: (1) the auditory-visual recognition of sentences recorded with the transparent mask was significantly better (M = 68.9%) than for sentences recorded with the opaque mask (M = 58.9%) for all participants. (2) The results of the auditory-only presentation of the sentences to listeners with normal hearing suggested that the transparent mask benefits were not attributable to an acoustic advantage but rather to the addition of the visual cues. (3) The performance in the auditory-only presentation was significantly lower with the transparent mask (M = 40.7%) compared to the opaque mask (M = 58.2%). They concluded that the use of transparent masks could facilitate speech recognition in noise even for persons with normal hearing and might reduce stressful communication challenges experienced in medical, employment, and educational settings during the global pandemic and the safety-approved transparent masks were strongly encouraged over opaque masks.

METHOD

Aim of the study

- To systematically review the impact of face masks and communication in the D/deaf/Hard of hearing (HOH) younger and middle adults during COVID-19 pandemic.

Objectives

- The primary objective of the present study is to review and discuss the research literature for the studies regarding the D/deaf/Hard of Hearing (HOH) younger adults' (18-35 years old) and middle adults' (36-64 years old) impact of face masks and communication during COVID-19 pandemic.

PRISMA guidelines 2009

This review was conducted by selecting the qualitative studies using PRISMA guidelines (Moher, D., Liberati, A., Tetzlaff, J. & Altman D.G., 2009). PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) is an evidence-based minimal set of items designed to assist writers in reporting a variety of systematic reviews and meta-analyses, which are generally used to assess the benefits and hazards of a health care intervention. PRISMA focuses on writing strategies to guarantee that this type of research is published in a clear and comprehensive manner. QUOROM (QUality Of Reporting Of Meta-analyses) was replaced by the PRISMA standard.

PRISMA 2009 flow diagram

Step `1: Preparation

To finish the PRISMA diagram, download it from the PRISMA website and print it out to use with your searches. You'll need to make a copy that includes totals from all of the databases, but you might also wish to create a copy for each database you search. If you're working on a more complicated project, check with your supervisor to see if they prefer you to use this system or include totals for each database in your final PRISMA diagram.

Step 2: Doing the database search

Enter each key search word separately for each database. This should include all of your search phrases, as well as all of the potential combinations of search terms. Once you've combined all of your search terms and applied all appropriate limits, you should have a number of records or articles that you can enter in the top left box of the PRISMA flow chart for each database. If you searched each database separately, tally up all of the 'records identified' and enter this total in the PRISMA flow diagram. If you search databases, keep in mind that the procedure of adding up the number of documents in different database searches to a total will need to be repeated at each stage.

Step 3: Additional sources

If you located articles using methods other than databases, such as manual searches via reference lists of papers you found or search engines such as Google Scholar, enter the total number of entries in the box on the top right of the flow diagram.

Step 4: Remove all the duplicates

To prevent examining the duplicate articles, eliminate any that occur more than once, and manually remove any duplicates from all the records or articles you've located in the database. If you have a huge number of articles at this point, this is difficult to accomplish. You could wish to export the complete list of articles to a citation manager and delete the duplicates there. In the second box from the top, enter the number of records left after you've deleted the duplicate.

Step 5: Screening articles

The next step is to input the number of articles you've screened, which should be the same as the number you put in the duplicates removed box.

Step 6: Screening excluded articles

You'll now need to look over the titles and abstracts of the papers to see if they're relevant to your study. Include any publications that appear to help you in providing an answer to your study. In the appropriate box (next to the total number of screened records), enter the number of articles that were excluded as a result of this screening process, along with a brief explanation.

Step 7: Eligibility

Subtract the number of articles that were excluded after the screening phase (step 6) from the total number of records examined (step 5) and enter the result in the "Full-text articles tested for eligibility" box. Review the full text of these articles to see if they are eligible.

Step 8: Eligibility- records excluded

Examine all full-text articles for inclusion in the final review. Take note of the number of articles you are excluding at this time and enter it in the correct box titled: Full text articles excluded, followed by a brief explanation of why you are excluding the articles (this may be the same reason used for the screening phase).

Step 9: Included

The number of excluded articles or records during the full-text eligibility review (step 8) is subtracted from the overall number of articles assessed for eligibility (step 7). Fill in the qualitative synthesis box with this number. In the quantitative synthesis box, you would additionally specify the number of studies if you were doing a meta-analysis. You've finished your PRISMA flow diagram, which you can now put into the research results portion of your article or assignment.

Eligibility Criteria

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were utilized in this study. The eligibility criteria were established to ensure that the research article papers were chosen in a methodical and fair manner. The population of interest was defined and included as the D/deaf/Hard of Hearing (HOH) younger adults (18-35 years old) and middle adults (36-64 years old) and the populations describing the infants, children, teenage (or) adolescents and the older adults (or) seniors were excluded. A search was conducted to identify the studies that evaluated the outcomes of face masks and communication in younger and middle adults associated with hearing loss (D/deaf/HOH) and COVID-19 pandemic.

Inclusion criteria

All the studies regarding younger and middle adults with hearing loss and hearing disabilities, D/deaf/HOH communities/college students, Cochlear implant users, face masks and coverings, masked world, communication and COVID-19 related studies are all included.

Exclusion criteria

All the studies regarding educational challenges, distant and masked education, classroom, school children/students, aural rehabilitation and telepractice, D/deaf/HOH children, adolescents and older adults, reviews and systematic reviews, viewpoints, case studies, medical condition and psychological study, typical-hearing listeners, not relating to face masks and hearing loss, other departments/fields and pre-prints are all excluded.

Information sources and Search Strategy

The relevant studies were identified through electronic searches of PubMed (MEDLINE) and Google Scholar. Google Scholar was used to identify the further grey literature. Reference lists and citation tracking were screened to identify any additional relevant studies. The search strategies were developed and tested through an iterative process. The following search terms and keywords were used: 'face mask', 'communication', 'COVID-19', 'hearing loss', 'D/deaf/Hard of Hearing (HOH)' and 'adults with hearing loss'. No language restrictions were imposed in these searches.

Data management and Study Selection

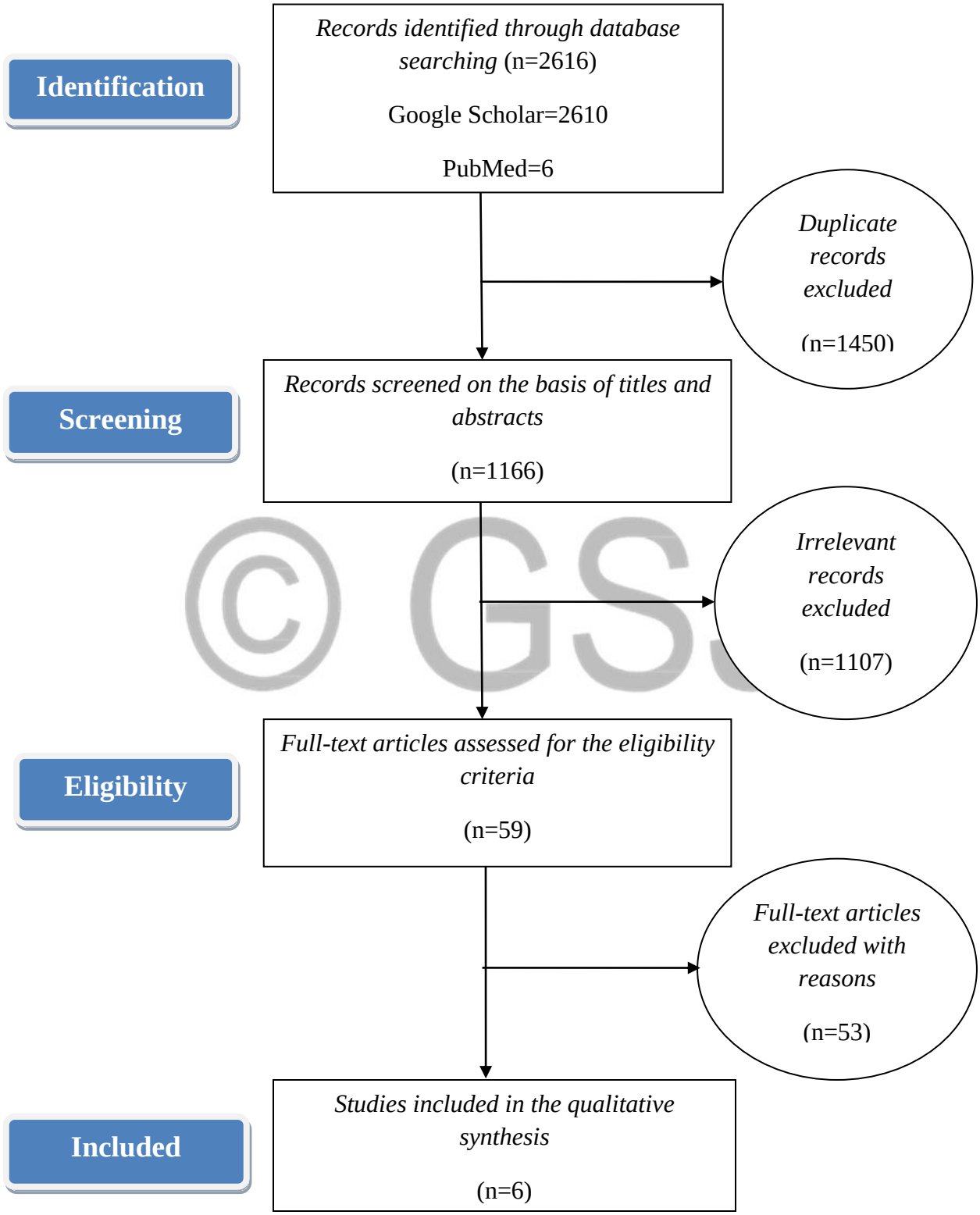
The abstracts of all the citations found in the searches were subjected to a twofold review process. Duplicate records were found and removed manually. In all the research article studies that met the inclusion requirements, the title and abstract were evaluated for eligible criteria, and the complete text was examined. The entire texts of documents that passed the initial check were read to assess eligibility. Only the studies that met the qualifying criteria were included in this systematic review, and any discrepancies were handled through discussion. A PRISMA-P flow diagram was used to describe the screening process and results.

Data Collection and Data Items

For the publications that were considered eligible, a uniform data extraction sheet was employed. Study characteristics (study title, authors, and date of publication, publication type, study site, and number of subjects), population characteristics, and associations between hearing loss (D/deaf/HOH) and COVID-19, and face mask and communication were retrieved from the eligible included studies.

Figure: 3.1

PRISMA guidelines for the selection of the articles included in the review



RESULTS AND DISCUSSION

Study Selection

A total of 2616 articles were identified through Google Scholar (2610 articles) and PubMed (6 articles). The 1166 articles were screened on the basis of titles and abstracts where the duplicates (1450 articles) were removed and excluded. From these 1166 articles, 59 full-text articles met the eligibility criteria where the remaining 1107 articles were excluded and eliminated which were obviously different not relating to speech and hearing field or irrelevant. After assessing and inspecting the 59 full-text articles according to inclusion and exclusion criteria, the 6 articles were deemed eligible and so included in the qualitative synthesis and the remaining 53 full-text articles were excluded and eliminated due to educational challenges, distant and masked education, classroom, school children/students, aural rehabilitation and telepractice, D/deaf/HOH children, adolescents and older adults, systematic reviews, viewpoints, typical-hearing listeners, case studies, medical conditions and psychological study, not relating to face masks and hearing loss, other departments/fields and pre-prints The screening process and the results are depicted in a PRISMA-P flow diagram.

Table 4.1

Study design and the articles selected for the study

Authors	Year	Country	Journal	Name of the article
Homans and Vroegop	2021	Rotterdam, Netherlands	International Journal of Audiology	The impact of face masks on the communication of adults with hearing loss during COVID-19 in a clinical setting
Garg, Deshmukh, Singh, Borle and Wilson	2021	Delhi, India and North Carolina, U.S	Indian Journal of Community Medicine	Challenges of the Deaf and Hearing Impaired in the Masked World of COVID‑19
Homans and Vroegop	2021	Rotterdam, Netherlands	Laryngoscope Investigative Oto-laryngology	Impact of face masks in public spaces during COVID-19 pandemic on daily life communication of cochlear implant users
Atcherson, McDowell and Howard	2021	Arkansas, U.S	Journal of the Acoustical Society of America	Acoustic effects of non-transparent and transparent face coverings
Saunders, Jackson and Visram	2021	Manchester, U.K	International Journal of Audiology	Impacts of face coverings on communication: an indirect impact of COVID-19
Thibodeau, Nielsen, Tran and Jacob	2021	Texas and Missouri, U.S	Ear and Hearing	Communicating During COVID-19: The Effect of Transparent Masks for Speech Recognition in Noise

Table 2

Communication difficulties caused by the face masks and the degree of hearing loss

Authors	Total participants	Study Design	Age range	Degree of HL	Communication difficulties or challenges
Homans and Vroegop	42 patients Cochlear Implant users=23 Hearing Aid users=19	Prospective observational study	31-85 years old	Moderate to severe HL	Surgical mask and face shield- negative effect.
Garg, Deshmukh, Singh, Borle and Wilson	D/deaf/HOH (hearing-impaired) children and adults	Literature review survey	N/A (not applicable)	HL >40 dB in better hearing ear in adults. HL >30 dB in better hearing ear in children	Deprivation of accurate and reliable information on COVID-19. Lack of communication with D/deaf children at home. Lack of proper sign languages.
Homans and Vroegop	407 adult Cochlear Implant users 221 adult CI users participated (54% female)	Prospective survey study	18-92 years old	Severe to profound HL	The widespread use of face masks-complicated the daily life communication of CI users and reduced the quality of life.
Atcherson, McDowell and Howard	D/deaf/HOH individuals (adults)	Acoustic study	N/A (not applicable)	Severe to profound HL	The presence of visual cues remained important for both verbal and non-verbal communication (transparent masks).
Saunders, Jackson and Visram	460 individuals Female=365 (79.5%) White=429 (93.3%)	Online survey (self-reported hearing)	18-89 years old	Normal hearing sensitivity to profound HL	The face coverings – impacted communication content, interpersonal connectedness and willingness. Increased anxiety and

					stress and made communication fatiguing, frustrating and embarrassing.
Thibodeau, Nielsen, Tran and Jacob	162 adults Normal hearing=136 Assistive listening devices users =14 Without the use of assistive listening devices=12	Online study	18-64 years old	Normal hearing sensitivity to confirmed or suspected HL (mild-profound HL)	The use of transparent masks –facilitate speech recognition in noise might reduce stressful communication challenges experienced in medical, employment, educational settings.

Homans and Vroegop (2021) investigated the effect of surgical masks and face shields on speech intelligibility of adults with moderate to severe hearing loss and measured speech tracking scores in quiet for life speech without surgical mask, surgical mask and face shield. The study sample consisted of 42 patients with moderate to severe hearing loss, 23 Cochlear Implant users and 19 Hearing Aid users. They found in acoustic analysis, the decibel difference between the face shield and surgical mask when compared to a condition without a mask as a baseline. Because there were no differences below 250 Hz, they didn't show the measurements in the graph and then the three test–retest situations all had similar patterns and no significant differences. Similarly in effects of protective equipment on the Speech Tracking Scores (STS), they displayed the STT findings for three conditions: without protective equipment, with a face shield, and with a surgical mask.

The Paired Samples T-test indicated that a significant average difference in STS existed between the situation without surgical mask and with surgical mask and between without surgical mask and with face shield. For the whole group of participants, no difference was found between the condition without surgical mask and with face shield.

For subjects with CVC test phoneme score <80%, also a significant difference between without surgical mask and with face shield. Moreover, in STS and patient related factors, they assessed the relationship between patient-related factors and STS for the effect of surgical masks since they had the greatest impact on speech perception. They showed the effect of the surgical mask per patient on the STS. They subtracted the STS with surgical mask from the score without surgical mask. The surgical mask has a greater effect on STS when the result is larger. The CVC test results in the best aided condition and the impact of surgical masks were shown to have a significant correlation of -0.58The PTA and the effect of surgical masks were shown to have a significant association of 0.72 for HA users. There were no significant age-related differences in the influence of the surgical mask on speech scores. On the effect of the surgical masks, there were no significant differences between HA and CI users.

They examined and discussed at how IIR surgical masks and face shields affected speech perception in adults with moderate to severe hearing loss and found that the face shields had the most acoustic impact on vocal sound. In the acoustic analysis, the face shield had the worst acoustic performance, which was consistent with previous research on the acoustic effect of surgical masks (Corey, Jones & Singer 2020; Maryn, Wuyts & Zarowski 2021; Vos et al. 2021). The surgical mask showed the greatest attenuation for frequencies above 2 kHz, with a maximum of 5 dB and they discovered a 3 dB sound amplification between 500 and 1000 Hz for the face shields, and a 6 dB sound attenuation for frequencies over 1 kHz. In the effect of protective equipment on STS, they discovered that the listening situations with surgical masks had much poorer STS than the listening situations with a face shield or the listening situations without a surgical mask. The face shield had no discernible variations from the listening condition without a mask. In the effect of protective equipment on STS, they discovered that the listening situations with surgical masks had much poorer STS than the listening situations with a face shield or the listening situations without a surgical mask and the face shield had no apparent changes from the listening situation without a mask. Vos et al. (2021) showed no changes between the surgical mask and the listening situation without a mask, but a lower score for speech perception when a face shield was added to the mask situation. According to Atcherson (Atcherson, McDowell & Howard 2021), face shields were likely to distort sound to a larger degree, but with the availability of visual information, this effect might be mitigated.

Even the face shield had a substantial impact on the STS for the worst performers on the CVC test (80%), indicating that people with poor auditory functioning required both auditory and visual signals for good performance. In the patient related factors and the impact of surgical masks, they discovered that the surgical mask's effect on STS was inversely linked with the standard clinical speech test (CVC test). This was similar to the findings of Vos et al. (2021). Even with visual cues present, the face shield had an impact on the STS of the worst performers.

The challenges faced by the deaf and hard of hearing (hearing-impaired) people during COVID-19 by a literature review was assessed by Garg, Deshmukh, Singh, Borle and Wilson (2021). The challenges and strategies for addressing the D/deaf/HOH (hearing impaired) during the COVID-19 pandemic were lack of information, lack of proper sign language, lack of communication with D/deaf children at home, face mask –a challenge for communication, social distancing –a barrier for physical and mental health, stigma and discrimination as a barrier, the barriers related to health-care system.

In the lack of information, D/deaf/HOH (hearing impaired) people were deprived of accurate and reliable information on COVID-19 due to the lack of availability of sign language specialists and inability to comprehend lip reading due to the face masks in direct communication. In the lack of proper sign language**,** people should avoid touching their faces and mouths during COVID19 to limit the spread of corona virus. As a result, the essence of sign language was lost, and crucial information was missed. Except for a few personal contacts and trainers, the general public dealing with the D/deaf community was unaware of the sign language. Frontline service providers didn't have time to learn a new language in order to help the D/deaf community. Sign language interpreters, D/deaf leaders and skilled interpreters should be there at every place without face mask/covering because he/she uses his/her lips and facial expressions in order to help and work with the D/deaf/HOH community to understand the current scenarios of the pandemic and news on the personal social media platforms.

In the lack of communication with D/deaf children at home**,** the majority of parents were unable to communicate effectively with their D/deaf children.

Because of the corona virus threat and the lack of a familiar environment as a result of the lockdown, those youngsters were likely to be confused, anxious, and depressed. Deaf instructors and sign language interpreters in schools should be provided with appropriate accommodations so that they can teach sign language classes to parents on weekends. They can advise parents and children on how to mentally and emotionally prepare for COVID-19 pandemic. This can assist D/deaf children in continuing their education at home and the instructors can teach parents how to use the additional visual resources with their D/deaf children.

In the Face mask- a challenge for communication, people who were deaf or hard of hearing felt isolated from the world. Deaf people who use sign language still required facial expressions to fully comprehend and those who use hearing aids or cochlear implants during rehabilitation rely on lip reading to better comprehend. Due to the facemask, anyone with a hearing impairment will have difficulty comprehending the muffled speech. As a result, masking one's face can limit one's capacity to communicate, particularly with the hearing impaired or deaf community. Essential service employees, health professionals, and public service providers that wear facial masks provide a barrier for the hearing impaired. In the Social distancing –a barrier for physical and mental health, the 6 feet suggestion for physical distancing during the pandemic provides a difficulty for the hard-to-hear population due to inaudible speech, resulting in social isolation and mental health consequences. The deaf and hearing impaired may not understand the next person's verbal communication and hence may not respond, leads to a sense of social isolation. A companion or family member and mental health counsellors should be there and work with the D/deaf/HOH (hearing impaired) people.

In the Barriers related to health-care system, D/deaf/HOH (hearing impaired) people encounter the challenges for hearing testing during COVID-19 pandemic due to the lack of consultation with the healthcare professionals. Due to the lockdown measures, getting an interpreter or a family member to accompany them to the health care institution is difficult. All of this might cause confusion and frustration in D/deaf/HOH (hearing-impaired) people. In many low-income areas, there are preexisting impediments such as a lack of services for fitting and maintaining assistive listening devices, as well as lack of batteries.

These services are unavailable due to the COVID-19 pandemic's strict lockdown, causing significant hardship to the users. The normal processes for donning and doffing PPE kits by healthcare practitioners make it impossible for them to doff the PPE for communication to address the challenges of the D/deaf/HOH (hearing impaired) people. They discussed and gave a list of COVID-19 resources and guidelines for D/deaf/HOH (hearing impaired) people, as well as referrals to health care facilities for emergency consultations.

The government should make videos in sign language for hearing impaired and D/deaf/ HOH people on valuable information, signs, symptoms, and preventive and control methods for COVID19 at home. For the D/deaf/HOH community, a COVID-19 hotline should be created, with telephonic and user-friendly links on the Internet, to get appropriate and timely information from health-care workers. D/deaf leaders and interpreters have to collaborate to build a community list of interpreters willing to offer their services and interpret video calls between medical professionals and deaf clients. National governments should make efforts to increase the development and management of assistive devices. Governments and charity organizations should collaborate to build some pick-up and repair sites during the lockdown. Newer developments, such as video conferencing, an interface to connect individuals via the internet, and m-health, were emerging as potential communication methods, and they had to be adjusted to the needs of the D/deaf/HOH community (hearing impaired). During video sessions, captioning services were frequently unavailable; despite that captioning was an important aspect of communication. The use of technology that allowed the D/deaf/HOH (hearing impaired) to have their calls or texts translated by an operator could help them communicate with the outside world.

Homans and Vroegop (2021) investigated the potential problems in the daily life communication of Cochlear Implant (CI) patients due to the widespread use of face masks in public places during the COVID-19 pandemic and used an online questionnaire (which consisted of face mask questionnaire, loneliness question and 3 sub-domains of the Nijmegan Cochlear Implant Questionnaire to assess the quality of life) about the effects of face masks on the daily life communication of adult CI users.

A total of 407 adult CI users were invited to participate. The loneliness question and Nijmegan CI Questionnaire were analyzed for the possible differences between the current situation with masks and the situation before when the masks weren't commonly used. The first section of the questionnaire about the face masks and loneliness in the present situation was completed by a total of 221 (100%) participants. A total of 220 people completed the NCIQ sub-domains for the present situation (99.5 %). In the condition where the face masks were not recommended and widely used in the public domain, 201 participants (91%) also answered the loneliness question and the NCIQ. However, due to the technical difficulties during the study's first phase, question 20 of the NCIQ was not asked for the condition before the face masks were employed, resulting in only 48 responses to this question.

In the face mask questionnaire, they showed the outcomes of the face mask questionnaire. In their communication, 80% of the participants had "regularly" to "almost always" problems with the face masks. For 83 % of the participants, the severity of the difficulties was graded as moderate to severe. Face masks made 59 % of the participants feel anxious about their communication "almost always". Losing their lip-reading ability had the greatest influence on 44 % of the participants who were having communication challenges, 14 % believed it was the disruption in sound quality, and 40 % thought it was equally important. They also inquired whether there were any other factors interfering with their communication. 3 participants stated that the lack of facial expressions was the most problematic, while 1 participant stated that the necessary distance of 1.5 m had a significant impact on the daily communication.

In loneliness, they showed that the participants scored much higher on the loneliness question than in the situation where the face masks were not commonly worn in the present condition. The rise in loneliness was weakly but strongly linked with age and gender, indicating that the elderly were less impacted by the pandemic and that the men were slightly lonelier than women. D/deaf participants also felt lonelier before communicating with the people.

In Nijmegan Cochlear Implant Questionnaire (NCIQ), they showed the results of the NCIQ sub-domains and questions. The NCIQ scores greatly declined in all the 3 sub-domains (Advanced sound perception: difference-10; Activity: difference-5; Social interactions: difference-2).They demonstrated that the 3 questions about the speech perception (discussion with one person, discussing with 2 or more people, and in a crowded shop) showed the most decline. The decline in NCIQ scores for the sub-domain of advanced sound perception was weakly associated with age, implying that the face masks had a less impact on NCIQ scores for elderly people than for younger people. Although no gender differences were observed, prelingually D/deaf participants experienced more impact on the Advanced Sound Perception Scale. No strong correlations were observed in the other NCIQ sub-domains.

They looked and discussed at the impact of face masks in public (interior) spaces on adults with severe to profound hearing loss that used a CI in the Netherlands, and discovered that wearing a face mask in public spaces had a significant impact on communication for CI users. In face mask questions, face mask users faced "regularly" to "almost always" communication challenges according to 80 % of the participants and those difficulties were described as moderate to severe by 83 % of CI users. According to Trecca et al 2020 and Naylor et al 2020, 97 % had some sort of issue. According to Naylor et al (2020), 93% believed that comprehending someone wearing face masks was more difficult, with speech distortion being the most common cause. Transparent masks had the worst acoustic performance of all the masks tested and wearing a face mask was particularly problematic for the CI users. In loneliness, the use of face masks in public areas made the participants feel lonelier. Some research on loneliness during the COVID-19 pandemic reported an increase in loneliness as a result of government security measures and they claimed that one of the variables contributing to loneliness among patients with significant hearing loss during the pandemic was the usage of face masks. They predicted that older CI users might spend less time in large groups and public areas than younger CI users, implying that the effects might be smaller and those had to rely on lip reading and might be greatly influenced by the face masks' input and also using the telephone to communicate with friends and family was less obvious. In NCIQ, the NCIQ's three sub-domains all revealed declines in performance, with the questions about speech comprehension deteriorating substantially and they found equal or lower scores on the various sub-domains.

On the other sub-domains, they also found equal or lower results, and the minor disparities might be explained that 22% of our subjects were prelingually deafened. They reported that more over half of the participants were above the age of 65, and that the elderly had lower NCIQ scores.

Atcherson, McDowell and Howard (2021) included some newer mask options as well as transparent masks to help deaf or hard of hearing that depended on lip-reading and other facial cues. In the acoustic attenuation of face covers, they showed the acoustic transfer functions of non-transparent and transparent face covers measured at 6 feet (i.e., suggested social distance). In comparison to the no-mask condition, the data points were plotted logarithmically. There appeared to be the minimal attenuation and changes below 1 kHz for most face covers, with larger attenuation and fluctuating differences in higher frequencies, validating the well-known low-pass filtering effect. Again, they revealed the computed rms level and the acoustic attenuation for the non-transparent and transparent face covers at 3 and 6 ft, respectively, compared to the no mask condition between 2 and 8 kHz. They showed the higher attenuation at 6-ft distances, on the order of 4 dB and 5 dB, respectively. Yet, when compared to the no mask condition, the acoustic attenuation between the distances was around 1–2 dB.

Similar to the results by Goldin et al. (2020) and Corey et al. (2020) the two surgical masks (I.1 and II.2) attenuated about 4 dB and the N95 respirator mask (I.4) attenuated about 6 dB and Atcherson et al. (2020) had slightly better outcomes on those results. The K95 respirator mask (I.3) attenuated about 6 dB had slightly poorer by Corey et al. (2020). The reusable PM2.5 respirator mask with replacement carbon filter (I.5) attenuated about 8 dB (greatest attenuation). The 2 cloth masks (I.6 and I.7) attenuated around 5-6 dB comparable to results by Corey et al. (2020) and the cloth mask with HEPA filter gave slightly more attenuation. When compared to the non-transparent face covers, the transparent face covers had more attenuation about 9 to 17 dB. Similar to Corey et al. (2020) findings, the face shield (II.1) and shield-like types (II.6, II.7, and II.8) appeared to amplify sounds in the 0.5–1 KHz range, and similar to Atcherson et al. (2020) findings, all the transparent face covers had unique “resonance-like” peaks between 5 and 7 KHz. Full face shields, as expected, performed badly when compared to the other non-transparent face covers, especially in the 1–3 kHz range.

The Safe ‘N' Clear (II.2) and FaceView (II.3) masks did the best, while the partial shield ClearMask (II.4) mask did the worst and then the transparent face covers allowed the listeners with and without hearing loss to see the face (in part or in full), but they diminished high frequency speech cues (Goldin et al., 2020; Atcherson et al., 2020; Corey et al., 2020).

In the acoustic attenuation of face coverings with a standard face shield, they compared the acoustic attenuation of all nose and mouth face covers with and without a generic plastic face shield (to protect the eyes) to the no mask condition. A condition was also reported that combined the face shield with a N95 respirator mask worn underneath a surgical mask (III.12). The inclusion of a face shield worn with one or more nose and mouth face covers generally resulted in a 10 to 16 dB increase in attenuation, for a total attenuation of 18 to 25 dB. Atcherson et al. (2020) observed significantly worse results when using the maximum single data point between 2 and 8 kHz, with face shield attenuation ranging from 8 to 20 dB and combined mask and face shield attenuation ranging from 20 to 29 dB.

In the directional effects of transparent face coverings, they revealed the directional effects of transparent face coverings as a function of angle for the head-shaped, custom mouth simulator with the “listener” microphone 6 ft away. The rms level for data points between 2 and 8 kHz was shown for each of the 15 degree rotations. In comparison to wearing no mask, all the transparent face coverings reduced sound transmission from all angles. In comparison to full face kinds, nose/mouth types appeared to have less restriction in the front and more attenuation on the sides and back. In comparison to the non-shield types, the shield-like types that covered the most, if not all, of the face [e.g., face shield (II.1), ClearMask (II.6), and Humanity Shield (II.7)] seemed to deflect and increased the sounds to the side and back. Because of the weaker sound transmission through two layers of cotton, the clear cloth mask (II.4) and Moog shield with apron (II.8) were among the most restricting. The directional plots were likely influenced by reflective surfaces at the booth's corners because all recordings were done in an audiology test booth. There appeared to be the correlations among variables such as the size of the window/shield, the distance between the window/ shield and the mouth, and the relative fit for all transparent face covers, which varied from person to person and how the face cover was worn.

The impact of face coverings on hearing and communication was studied by Saunders, Jackson and Visram (2021). An online survey consisting of closed-set and open-ended questions distributed within UK to gain insights into experiences of interactions involving face coverings and of the impact of face coverings on communication. A total of 460 members were recruited via snowball sampling and the people with hearing loss were oversampled to more thoroughly assess the effect of face coverings. In the demographic and hearing-related information, they showed individuals' ages as a function of their self-reported hearing ability. While the overall proportion of people who rated their hearing from "very good" to "very poor" had distributed equally across the rating categories, the distribution of rating categories within age groups followed the expected pattern of hearing decrease with age. Then, they showed the participants' use of assistive technology. The usage of assistive technology by 50% of participants was much higher than that of a random sample of the general population in the UK, suggesting that those with hearing loss were oversampled as predicted. They also showed a breakdown of hearing aid use in addition to showing the proportion of participants who used no technology, cochlear implants, and hearing aids. Hearing aids were employed "usually" or "almost always" by the vast majority of people.

In communicating with someone who is wearing a face covering, they indicated the number and percentage of people who had been in a communication situation where the speaker was wearing a face mask. 96 of the 137 "other" responses indicated communicating at work, a new category "work" were established. They illustrated how hearing, understanding, and feelings of being involved and connected were impacted when listening to someone wearing a face covering in each communication setting encountered by more than 50 participants. The participants stated that the face coverings had a negative impact on their hearing, understanding, engagement, and feelings of connection with the speaker, with very few exceptions. The negative effects of face coverings were found to be higher while communicating in medical situations (doctor, pharmacist, hospital visits) than when speaking with family/friends, shop assistants, and at work, according to a comparison of the red bars across the listening conditions.

In the interaction with hearing loss, using communication with family/friends and the doctor as examples, they highlighted the differential effects of hearing loss on the impacts of face coverings. They depicted how the face coverings affected the hearing ability and how they affected feeling engaged in the conversation. Also, they plotted as a function of self-reported hearing ability and hearing aid use. The difficulty people have hearing and feeling engaged in a conversation with someone who was wearing a facial covering was hugely affected by their degree of hearing loss, both as stated and as shown by the hearing aid use. This was confirmed in Kruskall–Wallis tests, which revealed the substantial variations between the responses based on self-reported hearing and the usage of hearing aids for communication with family/friends and the doctor.

In the thoughts about communicating someone who is wearing a face covering, they highlighted the themes, categories, and codes that emerged from the content analysis of the open-ended answers to the question, “In general, what are your thoughts about talking with someone who is wearing a face covering? Do you think it changes the way you communicate? If so, how do you feel about this?” as well as the example statements. The 7 themes were emerged such as hearing, visual cues, impact on the interaction, impact on the individual, impact on the behaviour, social impacts and big picture etc.

In communicating when wearing a face covering, 62% of the participants said they had been in a position where they had to communicate while wearing a face covering when the study was completed. 60% of the individuals stated that they communicated differently as a result of wearing a face covering, and 46% said that the nature of the conversation had altered, with 17% and 25% respectively answering "maybe." They highlighted the themes and categories that emerged from the content analysis of the open-ended answers to the questions, “In what way do you communicate differently when you are wearing a face covering?”and “In what way is the nature of your conversation different when you are wearing a face covering?” as well as the example statements. 4 themes with communicating differently were emerged such as delivery, body language, awareness of others’ needs and inward changes etc. The 2 themes with changes in the nature of communication also emerged such as impact on content and social impacts etc.

The wide range of responses to the open-ended questions demonstrated the general public's high level of concern about the communication issues related with face coverings. In fact, 83% of the participants supplied open-ended content, which was provided regardless of the self-reported hearing. In the perceptions of face coverings from a public health perspective, they depicted the responses to items testing participants' overall opinions regarding the face coverings and COVID-19 transmission as a function of self-reported hearing. In general, face coverings were deemed effective in terms of protecting the participants and others from COVID-19. The finding that the fewer participants agreed that more people should wear face coverings, however, was in direct opposition to this. It's worth noting that those views were formed regardless of whether or not a person had experienced hearing loss.

They discussed and demonstrated that the effects of face coverings on communication were far-reaching, extending far beyond their impact on speech transmission acoustics and face coverings influenced the substance of communication, emotions of interpersonal connection, and willingness to engage in discussion, as well as having a major negative impact on anxiety, stress, and self-confidence. Based on literature demonstrating the role of the mouth and lips in communication (Grant and Seitz 2000; Wegrzyn et al. 2017), as well as acoustic alterations related with face coverings (Goldin, Weinstein, and Shiman 2020), they concluded that the effects were unsurprising. They showed that the communication issues caused by face coverings were not confined to persons who have hearing loss and the effects were much stronger for people who reported hearing loss and/or who used hearing aids. Trecca, Gelardi, and Cassano (2020) found that more patients with hearing loss blamed surgical mask problems on their inability to lip read rather than muffled speech, and suggested that increasing face visibility to allow for speech-reading and interpretation of facial expressions might be an acceptable trade-off. Face coverings had different effects depending on the listening environment, with the effects on communicating in a healthcare context being stronger than those on interacting with a store clerk, family/friends, and at work and this could be taken as implying that the face covering's perceived impact was linked to a mix of the relevance of the material being discussed. Face covering communication challenges prompted a wide range of negative emotions, including worry, isolation, feeling dumb and losing confidence, and they suggested that the face coverings caused the same problems and same emotions, as hearing loss.

When wearing a face covering, several people reported they used gestures, facial expressions, and their eyes to improve communication, and they demonstrated that these kinds of communication might improve speech understanding (Drijvers and Ozyurek 2017; Jordan and Thomas 2011; Munhall et al. 2004; Wagner, Malisz, and Kopp 2014). They noted that while the survey was available online via social media to recruit participants, those who didn't use social media platforms would have been excluded, which would have included some of the most vulnerable to communication challenges by the usage of face coverings. As the usage of face coverings became more common in society, it seemed expected that the various styles would evolve for various purposes and situations. More research is needed to see how the different forms of face coverings affect communication and to inform future face covering designs.

Thibodeau, Nielsen, Tran and Jacob (2021) assessed the speech recognition in noise when using a transparent mask that allowed greater visibility of the talker's face compared to an opaque mask in persons with normal and impaired hearing via an online format. A repeated-measures design was used to evaluate the auditory-visual recognition of sentences recorded in background noise with transparent and opaque face masks and without a mask (N=154). The listeners completed the 40-minute online session on computer, laptop or tablet in a quiet room via their personal listening devices and the adult volunteers were recruited through social media links and email and categorized into 3 groups: normal hearing and confirmed or suspected hearing loss either with or without the use of assistive listening devices. They indicated the average percent accurate number of words successfully typed in the auditory-visual research for each condition (no mask, transparent, opaque) and hearing status [Normal hearing (NH), Hearing Loss without Assistive Listening Devices (HL-ALD) and Hearing Loss with Assistive Listening Devices (HL+ALD)]. A 3 x 3 x 2 repeated-measures ANOVA with mask type (no mask, transparent, and opaque) as the within-subjects factor (hearing status and sentence randomization set A or B) was used to see if the mask style affected sentence recognition. The significant effects of mask type and hearing status were summarized and there were no significant interactions or a main effect of the sentence randomization set.

In transparent vs opaque mask, the participants performed much better when listening to and observing a speaker wearing a transparent mask over an opaque mask, according to the *post hoc t*-tests on the significant main impact of the mask type. Given the average fluctuation of percent-correct speech recognition scores, Cohen's d effect size (0.69) was considered medium (Cohen, 1988). This finding revealed that transparent masks were important not only for those with hearing loss, but also for people who have normal hearing.

In transparent/opaque vs no mask, the participants were substantially less accurate in sentence recognition with the transparent mask than when listening and seeing with no mask, according to the *post hoc t*-test collapsed across subject groups. The 1.16 Cohen's d effect size was deemed extremely large, highlighting the significance of the findings. The performance with the opaque mask was much worse than the no-mask condition, as expected.

In the confidence and concentration ratings, they indicated how the participants' subjective evaluations of the challenges during the speech recognition tasks reflected their accuracy scores. For the confidence and concentration evaluations, two 3 x 3 x 2 repeated-measures ANOVAs were done, controlling the same factors as before (mask type, hearing status, and sentence randomization set). They also demonstrated that there was a significant main effect of mask type and hearing status on confidence ratings, but no significant interactions. The participants were more confident while listening to and viewing a speaker without a mask than when listening to and watching a speaker wearing a transparent mask or an opaque mask, according to *post hoc* assessments of the mask type. Also, the confidence was much higher for the transparent mask conditions than for the opaque mask conditions, as expected. *Post hoc* analysis of the primary effect of hearing status on confidence ratings revealed that the HL+ALD group had considerably lower confidence than the NH group and also less than the HL-ALD group, but not much. The two groups of people who had normal hearing or suspected hearing loss but did not utilize the technology had similar ratings. The results of the second repeated-measures ANOVA for subjective concentration evaluations in each condition were similar to the confidence results. When comparing the two types of face masks, participants stated that listening to and watching a speaker wearing a transparent mask required less concentration than listening to and watching a speaker wearing an opaque mask, as would be predicted.

They showed that the concentration ratings by hearing status followed the same pattern as the speech recognition scores, with the HL+ALD group reporting higher concentration than the other two groups (NH and HL-ALD), which had equal ratings.

In the auditory-visual (AV) vs auditory-only (AO) presentation follow-up study, a follow-up study was performed to ensure that the transparent's advantages over the opaque were not due to changes in acoustic intensity and/or quality in the custom-made mask used to collect the opaque and transparent conditions. Even though the attenuation effects of the opaque and transparent masks showed very minor differences (1.09 dB), there was still concern about possible distortion effects that would not be captured by a simple attenuation comparison. A more homogeneous sample of young, maybe more sensitive listeners was recruited in order to capture the effects of any quality or intensity variations in the recordings created with the opaque and transparent masks that might affect speech recognition.

They also represented the typical percent correct recognition scores for auditory-only stimuli recorded with opaque and transparent masks. The opaque mask condition outperformed the transparent mask condition in a paired samples t-test. This lower performance with the transparent mask in the auditory-only condition compared to the opaque mask supported the conclusion that the transparent mask's increased speech recognition was due to the inclusion of visual cues from the lips, tongue, and jaw rather than acoustic effects. The performance of normal-hearing listeners who received auditory-visual cues vs those who got the similar auditory cues but no visual cues was fascinating to compare. If the SNR remained constant, talking with someone wearing an opaque or transparent mask when turned around would be similar. This comparison would provide insight on the potential for seeing cues on the face other than those provided by the lips and mouth to bring additional benefits. To assess the performance of normal-hearing persons when given auditory-visual cues vs auditory-only stimuli, two independent-samples t-tests were done. There were no significant changes in sentence recognition scores between the opaque mask and the non-obtrusive mask conditions. In other words, whether participants could see and hear the speaker when wearing an opaque mask or could only hear the speaker when wearing an opaque mask, they all did badly.

When comparing the transparent mask conditions, auditory-visual vs auditory-only, there were substantial variations in performance. The participants that received both audio and visual input outperformed those who only got auditory input. The transparent mask allowed persons with normal hearing to get more facial cues to identify the sentences more precisely despite the decline in acoustic cues produced by the transparent mask, resulting in an extremely large effect size of 1.48 as depicted by Cohen's d.

They discussed and demonstrated that those who self-reported using hearing technology had more difficulties in all of the situations than those who had normal hearing or hearing loss but did not use technology. When comparing the performance of those who self-reported using assistive listening devices to those who didn't, the large Cohen's d suggested that this trend was significant. When receiving the auditory visual signals, individuals did much better with the transparent mask than with the opaque mask and the advantages of the transparent mask vs the opaque mask went beyond greater speech recognition and the listeners reported a considerable gain in confidence and a reduction in concentration effort. They demonstrated that when those with normal hearing responded to and watched auditory-visual stimuli, there was a 30% gain for the transparent mask condition as compared to auditory-only stimuli and highlighted that even people with normal hearing could benefit from wearing the transparent face mask. The numerous studies had looked into the attenuation effects of various mask types in order to reduce the acoustic discrepancies between the mask types. They used measurements using steady state signals like white or pink noise at the distances of three or six feet from the source to translate the findings of mask attenuation effects to speech recognition issues and the signals were likely altered in additional ways when communicating in the real world with face masks. They found that wearing transparent masks increased confidence and reduced concentration, resulting in greater overall communication success, and that wearing transparent masks allowed for the visibility of affect and possibly an emotional connection to relate to people even when social distancing was required. They suggested employing more eyebrow movements, including frequent gestures or body language, and wearing transparent face masks, among other things, to lessen the adverse affects on emotional information processing. They required the visual reinforcement of a positive affirmation as they developed social competency and attempted to learn under adversity.

Hearing-impaired children and adults were particularly vulnerable, as many are still learning to communicate and require optimal access to communication models and visual clues (Knowland et al. 2016; Saad et al. 2020). Some claimed that the transparent masks impeded visibility due to a "fog effect" generated by moisture released during speech and the remedies ranged from just spraying a thin film of liquid soap or bubbles to more expensive anti-fog methods (McNally and Childress 2020) and using the face shield would likely provide equal visual benefits. The alternative options for overcoming communication obstacles induced by face masks include using captioning applications on a smartphone or a communication board (McKee et al. 2020), as well as a remote microphone on the talker and a wireless receiver on the listener (McKee et al. 2020). They proved that the remote microphone technology improved speech recognition in noisy environments (Thibodeau 2020), but the impact of combining the technology with auditory-visual cues over auditory alone had not been examined.

SUMMARY AND CONCLUSION

The present systematic review highlights and focuses on how wearing the face masks and the face shields impacts the communication for the D/deaf/Hard of Hearing (HOH) younger and middle adults during COVID-19 pandemic.

In this study, from the six articles, there were four articles (Homans et al. 2021; Garg et al. 2021; Homans et al.2021 & Atcherson et al. 2021) discussing about the communication challenges by the D/deaf/HOH adults when the speaker was wearing facial coverings and the other two articles (Saunders et al. 2021 & Thibodeau et al. 2021) explained about the communication challenges by both the normal hearing and D/deaf/HOH adults when the speakers were wearing facial coverings during this pandemic. The communication challenges were faced not only D/deaf/HOH adults, but also by every normal hearing adult when the speakers were wearing facial coverings like face masks/ face shields.

Also from this study, three articles (Homans et al. 2021; Garg et al. 2021& Homans et al. 2021) addressed the issue of social distancing. The communication impacts the D/deaf/HOH adults when social distancing is maintained even for at least a distance of 1 meter. Sometimes, even the normal hearing adults struggle to communicate when social distancing is maintained. Since social distancing is a barrier for communication, the D/deaf/HOH adults won't be able to respond and they won't agree for social distancing.

Three articles (Homans et al. 2021; Homans et al. 2021 & Thibodeau et al. 2021) out of six articles from this study discuss about the ALDs like hearing aids and cochlear implants. Hearing aid/Cochlear Implant users face a lot of trouble and struggle to comprehend the muffled speech and struggle to lip-read when the speakers wear face masks in everyday situations and this greatly impacts the quality of life. They often feel isolated, alone and of being ignored by the normal hearing people.

Also, they hesitate and struggle to buy new batteries, or ask for help in hearing aid/cochlear implant troubleshooting, programming and fine-tuning of hearing aids and mapping

of cochlear implants. These services were unavailable due to the COVID-19 pandemic lockdown effects.

In conclusion, overall this review finds that wearing both the face masks and the face shields have a greater and negative impact on clear and conversational speech and communication for the D/deaf/HOH younger and middle adults (or) the people with hearing loss during this COVID-19 pandemic.

Communication is affected in the form of reduced speech intelligibility, being unable to understand a person's expressions and moods.

Hence, the Governments, public, hearing individuals, and doctors/clinicians should be aware of and supportive of D/deaf/HOH younger and middle adults in this pandemic.

Limitations:

- There were more female participants than male in the included studies.
- Most of the studies were self-rated which can create biasness in the outcomes.
- Studies were based on questionnaire rather than any standard test material and equipment.
- Sample size was limited.

Future directions of the study:

- The gender of the subjects taken for future studies in the female to male ratio canbe equal.
- Standard test materials can be used to find out more reliable results.
- Sample can be increased.
- Special considerations should be maintained to overcome the communication difficulties.

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