Pandemic Effect: Degradation of Speech Reception Due to Medical Masks

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Abstract — **Wearing a non-medical mask or face covering helps reduce the spread of COVID-19 in the community. The use of non-medical masks or face covers changes communication for everyone, but this presents an additional challenge for people with hearing loss or communication difficulties. People with hearing loss may have difficulty hearing in difficult situations, such as in noisy places or when they cannot trust lip reading cues or body expressions. face. In this study, a survey is implemented where speech recognition level-based questions are asked to the participants. Then, the same questions are asked again for the cases where medical masks are worn. In doing so, participants are also asked to explain the main difference between the pandemic period and the time before pandemic. Results show that wearing a medical mask has a concrete impact on speech recognition and causes a degrade on hearing level.**

Keywords hearing loss, speech recognition, visual cues, small data analysis, qualitative data analysis

I. INTRODUCTION

Recently, COVID-19 was uncharted territory. The medical and scientific communities were thus faced with a global pandemic caused by an unknown virus and they had to quickly learn how to protect the public. The situation is complex and recommendations are reassessed as we learn more about the virus. Being flexible is a good thing, as changes to these guidelines are made with the aim of keeping us more secure based on scientific and actual findings. Recommendations must evolve to reflect the most recent scientific findings and consensus. Since it is known that infection occurs from liquid droplets expelled when you breathe, talk, cough or sneeze when people are nearby, it means you can infect someone without even realizing it. Therefore, the masks act as a physical barrier that prevents droplets from reaching the people. However, wearing a mask is not just about statistics. It is also an act of solidarity to protect others.

A study conducted by Duke University tested 14 different types of masks. From N95s worn by healthcare workers and fleece neck warmers to bandanas and homemade ones, they were able to visually observe the amount of droplets that come out of each type of mask.

N95s got the best results, followed by surgical masks. N95s are only required for healthcare workers performing special procedures on very ill patients in hospital. There is a worldwide shortage of these masks; they are therefore not intended for everyday use outside the hospital. Home-made ones made from different types of cotton or blends have also shown excellent results; these are the ones we should be wearing.

Knitted masks, bandanas and fleece neck warmers finished last. In fact, the fleece neck warmer even seemed counterproductive, as it breaks the big droplets into smaller ones. This finding means that the droplets spread more than if you weren't carrying any.

Regarding masks with an exhalation valve, the WHO and the Government of Canada do not recommend their use. As tempting as it is to buy one (they're made to breathe easier), they're actually ineffective in our fight against COVID-19 as they allow infectious respiratory droplets to be projected into the body. air. Since we want to keep our droplets to ourselves, this type of mask does not reduce the spread of the virus.

Masks muffle voices, making them harder to hear. Masks hide facial expressions and prevent lip reading. Without visual cues, people who have hearing loss or have difficulty communicating can have even more difficulty understanding what they are hearing. People who have communication problems may have difficulty making themselves understood through a mask [1].

Clear masks and visors allow people with hearing loss to use lip reading to better communicate and understand. It can also help people who have difficulty communicating participate in conversations and expressing themselves more easily. Transparent masks can be completely clear or have a transparent section allowing the mouth to be seen. Clear masks help people with hearing loss understand speech better in noisy places. Visors are transparent and cover the face down to the chin. Visors dampen the voice more than masks, so you may need to have a voice amplifier [2,3].

Wearing a mask can become a communication challenge in two ways. First, the masks cover the mouth, thereby removing any visual cues to speech that the patient might receive. Second, masks can impact the very acoustic properties of speech.

These visual cues are useful for everyone, but especially for people who are hard of hearing. Visual cues are particularly important for understanding the presence of background noise, as they provide additional information that is added to the degraded acoustic signal. The movements of the lips provide the interlocutor with useful time markers for the perception of words and sounds. In addition, they provide the listener with clues about speech sounds, especially consonants[4].

In this study, a survey is managed and speech recognition level based questions are asked to participants. Besides, the same questions are asked for the case where medical masks are worn. Participants are asked to explain the main difference between the pandemic period and during that period. Results show that wearing a medical mask has a concrete impact on speech recognition and causes a decrease on hearing level.

The rest of the paper is organized as follows. Section 2 summarizes existing studies in the literature. Section 3 defines the survey and the questions asked to the participants. Section 4 presents the results and finally conclusion and discussion are given in Section 5.

II. RELATED WORKS

In the literature, there are several studies aiming to indicate the impact of wearing a mask on hearing and speech. Speech blocked by surgical masks becomes a more important issue in the Era of COVID-19. Existing studies confirm that "over 80% of the message" comes through body language. The face is an integral part of our body and arguably the part that looks most quickly when trying to discern the emotions of the person in front of us. As the mouth is hidden and a series of muscles activated by emotions provoke facial expressions, this alters part of our communication.

Visual clues become more critical and more important than before. These visual cues can help a listener, normal hearing or with hearing loss, identify spoken words more accurately than with acoustic or visual information alone. Dell'Aringa et al. have shown that adding visual cues improves calm word recognition for patients with hearing loss, whether or not they are hearing aid. Atcherson et al introduce speech perception using the Connected Speech Test set to 65 dB SPL with a signal to noise ratio of +10 dB. Participants with hearing loss showed a significant improvement in accuracy when visual cues were present compared to a masked state without visual cues.

The eyes alone are really very uninformative. The lower face provides information that is very important to the viewer looking at that face and when some of this information is hidden from him, he can no longer understand what is actually being expressed by the person displaying the expression.

The following experiment conducted by [5] presents the impact of wearing a mask on speech recognition. Figure 1 presents the different types of masks for the conducted experiment.

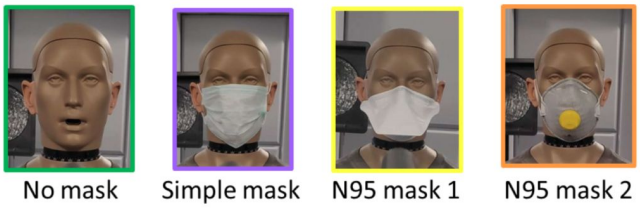

Fig 1. Experiment for detecting speech recognition while wearing different medical masks [5]

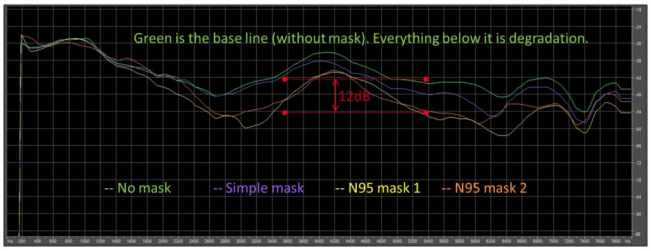

Fig 2. Output SPL level differences (in dB) for different types of medical mask shown in Fig 1 [5].

Figure 2 presents the degradation of the SPL levels for different types of medical masks. The data show that each mask essentially serves as a low-pass filter, attenuating the high frequencies (2000-7000 Hz) spoken by the wearer, with the decibel (dB) level of attenuation ranging from 3 to 4 dB for a simple medical mask and close to 12 dB for the N95 masks.

The acoustic impact of masks can also be very damaging. Goldin and Weinstein evaluated three types of medical masks: a simple surgical mask and two types of FFP2 masks. Their results indicated a reduction in high frequencies in the 2000-7000 Hz range of 3-4 dB for the surgical mask and about 12 dB for the FFP2 masks. Llamas et al. noted a 12 dB decrease in high frequencies for a certain type of surgical mask. Such studies evaluated several personal protective masks in an occupational health study. Two types of masks used in the assessment were FFP2 masks and general protection masks. The results showed a decrease in sound levels from 2000 Hz from about 1 dB for the protective mask to about 6 dB for the FFP2 on a dB-A octave band scale[5].

Rudge et al. report the differences in the speech perception capabilities of adults with normal hearing as they listen to the monitored live speech of a speaker that develops at 6 feet in nine different listening conditions, including four variants of face-covering with and without remote microphone technology, as well as a basic condition of no

face-covering and no remote microphone. The figure below shows the different types of face coverings used in the test conditions of this project [6]. Figure 3 shows the various types of masks for the conducted experiment and figure 4 shows the percentages of speech perception loss.

Fig 3. a. Textile mask b. Windowed fabric mask c. Fully transparent ClearMaskTM d. Facial display [6].

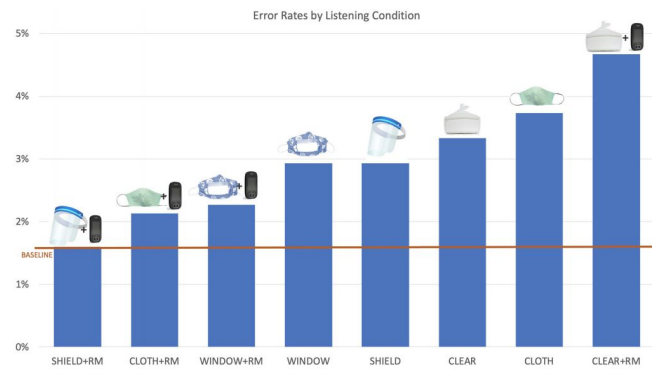

Fig 4. The percentage of speech perception loss assessed by the CNC test in nine variations of facial covering conditions, comprising the default condition of no facial coverage and no distant microphone (RM) shown by the orange horizontal baseline [6].

Table 1 shows the peak SPL decrease (in dB) for the various types of mask and for each type of mask in relation to a standard face shield versus the unmasked condition [7]. Such studies demonstrate the impact of medical masks on the level of speech recognition and how it degrades.

Table 1. Maximum Sound Pressure Level Reduction [7]

DEVICE	MASK ONLY	MASK + SHIELD
Surgical Mask	5.0 dB	20.0 dB
KN95 Mask	8.7 dB	29.2 dB
N95 Mask	10.9 dB	28.7 dB
FaceView Mask (transparent window)	12.0 dB	24.9 dB
Safe 'N' Clear Mask (transparent window)	13.3 dB	24.7 dB
Transparent Cloth Mask	21.2 dB	29.2 dB

III. STUDY

A survey is prepared and given to participants. The age distribution is presented in Figure 5. Besides the sex distribution of participants is illustrated in Figure 6. Prepared survey is asked to 1044 participants (622 female and 422 male having age from 15 to 90).

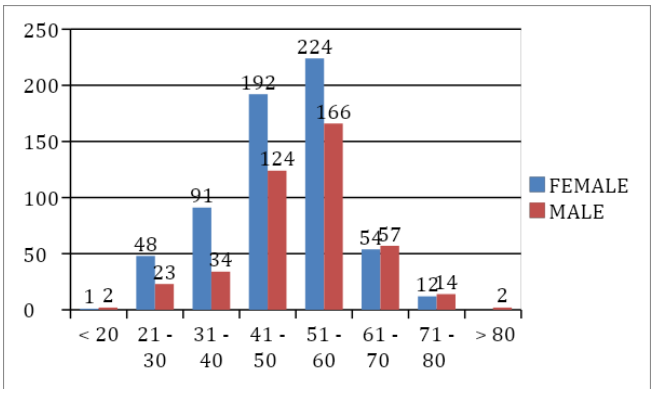

Fig 5. Age histogram of participants

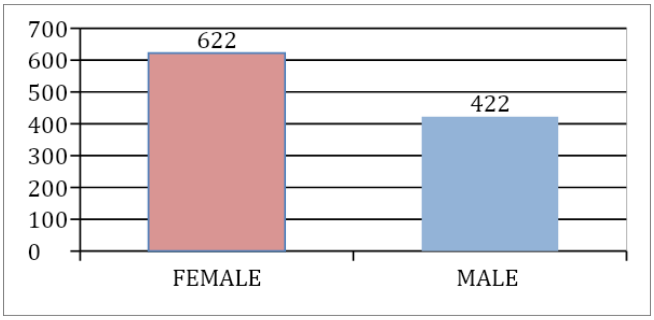

Fig 6. sex distribution of participant

The survey is prepared by an audiologist working in one of the largest private hospitals in Turkey. Respondents are asked to compare their hearing ability before the COVID-19 epidemic with the hearing ability required to wear a surgical mask after the epidemic in their daily lives routines. It contains 17 questions. 7 of these questions address directly the pre-pandemic period while 8 questions address the post-pandemic period. The questions are as follows:

General questions:
Q1: Age
Q2: Sex

Questions about the period before the pandemic:
Q3: Did you think you have hearing loss?
Q4: Would you have trouble understanding speech in noisy environments?
Q5: Did you need to turn the volume up while watching TV?
Q6: Would you find it difficult to hear sounds such as phone or doorbell?
Q7: Would you have trouble finding the direction where the sound is coming from?
Q8: Would you need to repeat the conversation?
Q9: Did you need repetition in face-to-face conversations?

Questions about the period while wearing medical mask:
Q10: Do you have trouble understanding speech in noisy environments?
Q11: Do you need to turn the volume up while watching TV?
Q12: Do you find it difficult to hear sounds such as phone or doorbell?
Q13: Are you having trouble finding the direction the sound is coming from?
Q14: Do you need to repeat conversations when people wearing masks speak?
Q15: Do you think the necessity to wear a mask makes it difficult for you to understand speech?
Q16: Do you find it difficult to follow conversations in masked environments?
Q17: Did you feel a change in your hearing during the pandemic?

```
print(df.dtypes)
df.info()
```

```
time                                                  object
age                                                    int64
sex                                                   object
hearing_loss                                          object
trouble_understanding_speech_in_noisy_environments    object
need_to_volume_up_tv                                  object
trouble_hearing_sounds                                object
trouble_finding_direction                             object
repeat_conversation                                   object
need_repetition_in_face_to_face_conversations         object
mask_trouble_understanding_speech_in_noisy_environments  object
mask_need_to_volume_up_tv                             object
mask_trouble_hearing_sounds                           object
mask_trouble_finding_direction                        object
mask_repeat_conversation                              object
mask_makes_difficult_to_understand_speech             object
mask_difficult_to_follow_conversations                object
feel_a_change_in_your_hearing                         object
dtype: object
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1042 entries, 0 to 1041
Data columns (total 18 columns):
 #   Column                                               Non-Null Count  Dtype
---  ------                                               --------------  -----
 0   time                                                 1042 non-null   object
 1   age                                                  1042 non-null   int64
 2   sex                                                  1042 non-null   object
 3   hearing_loss                                         1042 non-null   object
 4   trouble_understanding_speech_in_noisy_environments   1042 non-null   object
 5   need_to_volume_up_tv                                 1042 non-null   object
 6   trouble_hearing_sounds                               1042 non-null   object
 7   trouble_finding_direction                            1042 non-null   object
 8   repeat_conversation                                  1042 non-null   object
 9   need_repetition_in_face_to_face_conversations        1042 non-null   object
 10  mask_trouble_understanding_speech_in_noisy_environments  1042 non-null   object
 11  mask_need_to_volume_up_tv                            1042 non-null   object
 12  mask_trouble_hearing_sounds                          1042 non-null   object
 13  mask_trouble_finding_direction                       1042 non-null   object
 14  mask_repeat_conversation                             1042 non-null   object
 15  mask_makes_difficult_to_understand_speech            1042 non-null   object
 16  mask_difficult_to_follow_conversations               1042 non-null   object
 17  feel_a_change_in_your_hearing                        1042 non-null   object
dtypes: int64(1), object(17)
memory usage: 146.7+ KB
```

Fig 7. Data description

Before applying data science methods on the data, a preporcess is required to determine the missing answers on the dataset. Figure 7 presents the columns and descriptions of each column with their data structure and non-null counts.

For the data analysis, first, the distributions according to age and gender are obtained for the answers of each question. Secondly their totals were calculated again according to age and gender. Finally the correlation of the questions with each other is examined.

As a result of this last operation, it is observed that the correlation between the questions 4, 5, 6, 7, 8, 9 and the questions 10, 11, 12, 13, 14 and 15 was very low with the other questions. For this reason, these questions were matched among themselves and comparisons between 4th question with the 10th question; 5th question with the 11th question; 6th question with the 12th question; 7th question with the 13th question; 8th question with the 14th question and 9th question with the 15th question are realized in order to reveal the amount of the people affected by this change in their daily life routine. The correlations of the third, seventh, fifteenth, sixteenth and seventeenth questions with each other were found high. For these five questions a clustering operation via Apriori Algorithm is performed in order to determine the participant profile. To do this, first of all, the participants' age, gender and their answers to these questions were transformed into the boolean matrix given in Figure 8.

Age	Gender	Question #3	Question #7	Question #15	Question #16	Question #17
42	Female	False	True	True	False	True
44	Male	False	False	False	False	False
36	Female	False	False	True	True	False
45	Male	False	False	True	True	False
60	Male	True	False	True	False	False
45	Female	False	False	True	True	True
55	Female	False	False	False	True	False
43	Male	False	False	True	False	False
50	Male	False	False	True	True	False
48	Male	False	False	False	False	False
42	Female	False	False	True	True	False
53	Female	True	False	True	True	True
51	Female	False	False	True	True	False
53	Female	False	False	True	True	False
47	Male	False	False	True	True	False
56	Female	False	False	True	True	True
55	Female	False	False	True	True	True
41	Female	False	False	True	True	False
63	Female	False	False	False	False	False
66	Female	True	False	True	True	False
26	Female	False	True	True	True	True
43	Female	False	False	True	True	True
53	Male	False	False	False	False	False
53	Male	False	False	False	False	False

Figure 8. Boolean Matrix

All studies related to data analysis are carried out on Jupiter Notebooks using Python programming language and MS Excel. Results are interpreted in the following section.

IV. RESULTS

As stated in the previous section, the questions were analyzed in two different groups. The results of the first group analysis are as follows (given in Tables 2-10):

Table 2. Answers to Q3:
Do you think you have hearing loss?

	Yes	No	Total
Female	126	490	616
Male	122	299	421
Total	248	789	1037

Table 3. Answers to Q4: Would you have trouble understanding speech in noisy environments?

	Before			After		
	Yes	**No**	**Total**	**Yes**	**No**	**Total**
Female	304	317	621	396	220	616
Male	213	208	421	247	174	421
Total	517	525	1042	643	394	1037

Table 4. Answers to Q5:
Did you need to turn the volume up while watching TV?

	Before			After		
	Yes	**No**	**Total**	**Yes**	**No**	**Total**
Female	163	459	622	168	453	621
Male	174	245	419	171	248	419
Total	337	704	1041	339	701	1040

Table 5. Answers to Q6: Would you find it difficult to hear sounds such as phone or doorbell?

	Before			After		
	Yes	**No**	**Total**	**Yes**	**No**	**Total**
Female	42	578	620	53	566	619
Male	43	376	419	47	371	418
Total	85	954	1039	100	937	1037

Table 6. Answers to Q7: Would you have trouble finding the direction where the sound is coming from?

	Before			After		
	Yes	**No**	**Total**	**Yes**	**No**	**Total**
Female	60	561	621	110	509	619
Male	44	375	419	70	347	417
Total	104	936	1040	180	856	1036

Table 7. Answers to Q8: Would you need to repeat the conversation?

	Yes	No	Total
Female	59	560	619
Male	69	351	420
Total	128	911	1039

Table 8. Answers to Q15: Do you think the necessity to wear a mask makes it difficult for you to understand speech?

	Yes	No	Total
Female	428	194	622
Male	270	148	418
Total	698	342	1040

Table 9. Answers to Q16: Do you find it difficult to follow conversations in masked environments?

	Yes	No	Total
Female	396	219	615
Male	237	183	420
Total	633	402	1035

Table 10. Answers to Q17: Did you feel a change in your hearing during the pandemic?

	Yes	No	Total
Female	183	435	618
Male	99	321	420
Total	282	756	1038

As a result of second group analysis, 30 different clusters a.k.a participant profiles within the population are revealed. The 12 out of these 30 clusters can be excluded during the interpretation of the analysis since they have less than 5 people. The results are shown in Table 11 and the population ratios are presented in Figure 9.

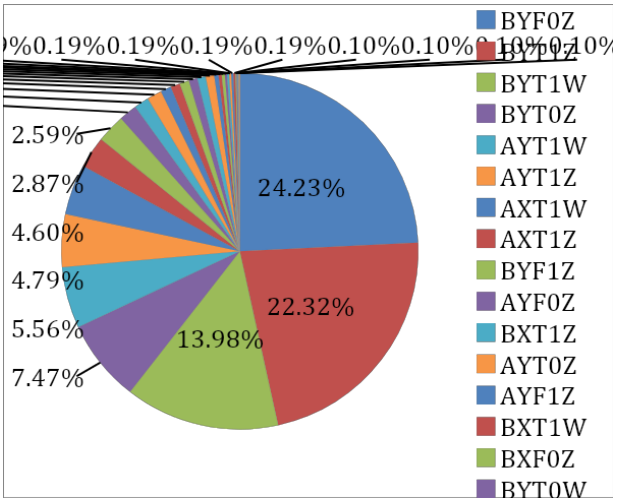

Figure 9. Illustration of 30 clusters and their population ratio

Table 11. 30 Clusters with their populations

Profiles	# of participants	%
BYF0Z	253	24,23%
BYT1Z	233	22,32%
BYT1W	146	13,98%
BYT0Z	78	7,47%
AYT1W	58	5,56%
AYT1Z	50	4,79%
AXT1W	48	4,60%
AXT1Z	30	2,87%
BYF1Z	27	2,59%
AYF0Z	17	1,63%
BXT1Z	14	1,34%
AYT0Z	14	1,34%
AYF1Z	10	0,96%
BXT1W	9	0,86%
BXF0Z	9	0,86%
BYT0W	8	0,77%
AXF1Z	8	0,77%
AXF0Z	8	0,77%
AYT0W	4	0,38%
BYF0W	3	0,29%
AYT1	3	0,29%
BYT1	2	0,19%
BYF1W	2	0,19%
BXF1Z	2	0,19%
AYF0W	2	0,19%
AXT0Z	2	0,19%
BYF0	1	0,10%
BXT0Z	1	0,10%
BXT0W	1	0,10%
AXT0W	1	0,10%
Total	**1044**	**100,00%**

Each cluster displays a specific profile of participants. Due to space constraints, the first three clusters are explained here. The cluster with the highest number of people, can be named as the *positive group* because the participants in this cluster consist of people who don't have hearing loss before the pandemic and don't need to repeat face-to-face conversations either. Moreover, these people state that after the epidemic started, the masks don't make it difficult to understand what is spoken, they don't have any difficulty in following the conversations in the environments with the mask, and that there isn't any change in their hearing after the pandemic.

The second cluster also consists of people who did not have hearing loss before the pandemic and did not need to repeat face-to-face conversations. However, the people in this cluster state that after the epidemic started, wearing a mask makes it difficult to understand what is spoken, and they also have difficulties following conversations in environments with a mask. Though they state also that there isn't any change in their hearing after the pandemic.

The third cluster consists of people who do not have hearing loss before the pandemic and do not need to repeat face-to-face conversations. People in this cluster, like the people in the second cluster, state that the mask makes it difficult to understand what is spoken after the epidemic started, and they also have difficulty following the conversations in environments where masks are worn. Moreover, they explain that there is a change in their hearing during the pandemic process. Since these first three groups constitute the majority of the total population, we took these clusters into consideration for the decisions we made about the general population. When we examined clusters with very low ratios in the total population, we came across a result like this. Within these clusters, there are clusters of participants that differ from the profiles defined in the clusters above with other features, but who indicate that the mask creates problems in understanding and hearing speech. The proportion of these clusters constitutes approximately 5% in general. Considering the number of participants in all these cited clusters and their percentage ratio among all the clusters, it can be said that wearing a mask has a significant effect on people's hearing.

V. CONCLUSION

The mask has become established in the social environment as a way to protect oneself from COVID-19. But wearing it hinders a whole section of non-verbal human communication. Mimicry, facial expressions - allies that may allow adjustments in the interaction - fade under the fabric. Only the eyes and the forehead then accompany the communication process. We must thus let go of a major element of the non-verbal, our smile. However, research has long shown its importance in the process of seduction.

Researches on this subject present that at any time during the school year, nearly one in five elementary students experience some temporary hearing loss (eg, from ear infections). About 66% of people 70 and over have hearing loss. Hearing loss has been recognized as the second most common form of disability around the world. More than 10% of school-age children have communication problems. At least 30% of people who have survived a stroke have difficulty communicating. Up to 90% of people with Parkinson's disease have communication problems.

In this study, a survey is managed and speech recognition level based questions are asked to participants. Besides, the same questions are asked for the case where medical masks are worn. Participants are asked to explain the main difference between the pandemic period and during that period. Results show that wearing a medical mask has a concrete impact on speech recognition and causes a decrease on hearing level.

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