Speech discrimination challenges of healthcare professionals whilst wearing Personal Protective Equipment (PPE) during the coronavirus disease 2019 (COVID-19) pandemic

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Abstract

Background Coronavirus disease 2019(Covid-19) Personal Protective Equipment (PPE) has been reported to effect communication in healthcare settings. We sought to identify those challenges experimentally. Method Bamford-Kowal-Bench speech discrimination in noise performance of healthcare workers was tested under simulated background noise conditions from a variety of hospital environments. Candidates were assessed for speech intelligibility with and without PPE both at normal speech and raised voice. Results There was a significant difference in speech discrimination scores between normal and PPE wearing subjects in theatre simulated background noise levels (70dB). Conclusion PPE wearing can impact communication and efforts should be made to remind staff about this burden and seek alternative communication paradigms, particularly in theatre environments.

INTRODUCTION

During the Coronavirus disease 2019 (Covid-19) pandemic, healthcare professionals have, where supplies exist, delivered care to their patients across the world wearing mandated Personal Protective Equipment (PPE)[1]. The authors anecdotally found communication and understanding wearing PPE to be drastically reduced in clinical areas, and impact on communication of PPE in general has previously been raised in popular press[2] and scientific literature[3,4,5]. We sought to assess these difficulties through a simulated clinical environment model.

In the clinical context, workers frequently speak and communicate with a degree of background noise, unlike the gold standard silent audiological testing booth. Pure tone audiometry (PTA) represents the "gold standard" test for hearing ability and is a good measure of hearing impairment. However, the audiogram generated by the PTA is a poor indicator of speech recognition in noise[6]. PTA measures hearing sensitivity rather than assessing the auditory and hence speech processing ability of the subject, therefore findings do not always correlate with the functional hearing ability of subjects faced with real-world signals and noise, such as speech[7]. A words-in-noise task adds significant cognitive load versus the same task without noise, and as in clinical settings where there is always a degree of background noise, a Speech in Noise (SiN) testing to be a better real world "stress test" of auditory function[8].

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Rather than a test of hearing, SiN testing for adults can assist clinicians in undertaking assessments of speech understanding in noise. A screening test that uses sentences rather than single words or phonemes is preferred than monosyllabic word lists presented in quiet conditions as the latter have demonstrated limited reliability and lack validity in relation to real-world simulations[9,10,11,12,13]. We sought to identify if there were genuine measurable challenges to speech discrimination wearing Covid-19 PPE in the present study by SiN tests.

METHOD

We sought to reproduce background noise in the clinical context by adjusting the signal to noise ratio (SNR) during testing. We chose adaptive SNR, using the Bamford-Kowal-Bench (BKB) Sentence Lists read by a clinician[14] whilst a PARROT machine[15] produced the background babble noise (simulated speech such as you might hear in a crowded pub or emergency department) at predetermined levels of noise. The PARROT is a portable digital speech screening system used to assess speech discrimination using a range of recognised speech discrimination tests.

The BKB sentences used in this test were published in 1979 as a protocol for testing hearing impaired children and developed as a SiN test by Niquette et al, 2003[16]. There are 10 sentences in each list with 18 lists. Each sentence has three or four words which must be repeated by the subject.

A percentage score can be given for how many words are correctly repeated.

To determine background noise levels in our hospital we conducted 2x 30 second sound meter recordings (ATP Digital sound level meter/ 8928, [calibrated by NHS audiometric calibration service, Audiology department, Withington community Hopsital, Manchester]) in 4 discrete environments; The office, the emergency department (ED), the intensive care unit (ITU) and the operating theatre during normal, daylight working hours.

Background noise level minimum and maximums (during daylight hours with regular levels of staff) were recorded as follows:

40-55dB Office 48-66dB ED 50-78dB ITU 53-84dB Theatre

Five candidates representing our hospital ENT department were chosen, 2 women and 3 men. Age range was 29-49 years. Median age of candidates was 39 years old.

Initial 250Hz – 8kHz Pure tone audiograms were conducted to confirm no significant hearing loss in our 5 candidates, who had no previous otology history or significant co-morbidity.

All testing was conducted in a soundproofed audiometry booth. Baseline Standard BKB sentences were conducted in silence for all candidates without PPE. Scores were 100% for all candidates.

We then conducted BKB sentence testing whilst each subject wore the facial PPE suitable for aerosol generating procedures (AGPs) (fit-tested FFP3 mask and head visor). All subjects had previously undergone fit testing to ensure that the PPE worn was fitting appropriately for each individual.

The researcher spoke using the BKB word lists whilst wearing AGP PPE. The subject wore the same PPE at a distance of 2m. The PARROT machine was placed behind and above the head of the researcher (Parrotplus 2, produced by Soundbyte). Background noise (adult) babble settings were chosen as characteristic values representing different environments as follows:

45 dB Office 55 dB ED 65 dB ITU 70 dB Theatre

Each candidate underwent BKB testing at the 4 background noise levels, in three test conditions:

a) Candidate and researcher in normal conditions without PPE, normal researcher voice b) Candidate and researcher both in AGP PPE, normal researcher voice c) Candidate and researcher both in AGP PPE with researcher attempting to raise voice.

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Raised voice was deemed researcher voice raised to the point at which the researcher felt their voice was comprehensible against background noise.

The percentage of key words in the BKB sentences repeated by the candidate was recorded. Each sentence was read once by the researcher and was not repeated.

During day-to-day working and conversation, people do not speak at the same intensity during the whole conversation and background noise also fluctuates rather than remaining at constant levels, hence our decision to use live, fluctuating voice rather than pre-recorded voices amplified to a fixed and constant volume[17]. When speakers adjust their voice to overcome background noise, this is known as the Lombard effect. Although attempting to raise one's voice or shout usually causes only a small increase in volume between 5-10dB[18], we chose to measure the volume of voice produced by the researcher as a secondary outcome measure. This was not our primary concern as attempts to raise one's voice in day to day clinical practice will have both inter and intra-person variability, so we felt the integrity of the simulation was preserved regardless of actual volume levels produced by the researcher.

Statistical analysis

Primary outcome measures were; 1: differences in BKB sentence results in different stimulated environments; office, ED, ITU and theatre and 2: differences in BKB sentence results with different PPE equipment scenarios; no PPE, wearing PPE and wearing PPE whilst raising voice volume.

Secondary endpoints were; 1: measurement of mean change in voice volume in response to increase in background noise and 2: mean SNRs with different PPE equipment scenarios and environments.

Data were analysed using IBM SPSS Statistics Subscription (IBM, Armonk, USA). Differences in BKB scores for different PPE equipment simulations in each hospital environment were calculated using one-way repeated ANOVA tests. For any environment found to have a statistically significant result, further comparison of differences in BKB sentence results with different PPE equipment scenarios were analysed using the Wilcoxon Signed-Rank test. A p-value of <0.05 was considered significant. The Wilcoxon signed-rank test was used as it compares dependant rather than independent samples.

Patient and Public Involvement This research was conducted without patient involvement. Patients were not consulted to develop outcomes or interpret the results as the focus was staff communication. This may occur if this research is expanded to include clinician-patient communication in the future.

RESULTS

Table 1 presents the BKB results for the 5 people entered into the study.

Table 1

One-way repeated-measures ANOVA indicated that different levels of PPE use did not significantly alter BKB sentence results in office or ED settings ($p = 0.26$ and $p = 0.58$ respectively) but showed a trend in ITU ($p = 0.06$). The statistical assumption of sphericity in the ITU setting was marginally violated; an effect perhaps due to the small sample size. If sphericity was assumed, the one-way repeated measured ANOVA test was statistically significant ($F_{(2,8)} = 6.64$, $p = 0.02$, $\eta p2 = 0.73$). Assumption of sphericity was not violated in the theatre setting results ($\chi2\,(2) = 3.13$, $p = 0.21$) and different levels of PPE use significantly altered BKB sentence results ($F_{(2,8)} = 17.16$, $p = 0.001$, $\eta p2 = 0.81$).

A Wilcoxon Signed-Rank test indicated that BKB sentence scores were significantly lower for subjects wearing PPE (median score 58) compared to those without PPE (median score 92) in a theatre simulated environment ($Z = -2.02$, $p = 0.04$). Increasing voice volume whilst wearing PPE significantly increased BKB sentence scores (median score 86) compared to normal speech volume when wearing PPE (median score 58; $Z = 2.03$, $p = 0.04$). There was no significant difference in BKB scores when wearing no PPE (median score 92) compared to when raising voice volume whilst wearing PPE (median score 86) ($Z = -0.68$, $p = 0.50$).

3

Our secondary outcome measure was mean change in volume of voice when wearing PPE. The increase in background noise rose by 25db from 45 dB (simulated office) to 70dB (simulated theatre). Our researcher elevated their natural voice by 13-20dB without PPE in response to simulated increasing sound levels which correlates with existing studies showing a natural shift to maintain signal-to-noise ratio in human speech[18].

Mean voice volumes across all simulations tended to increase with PPE wearing and increase again with PPE wearing and raised voice. The mean SNR achieved are shown in Table 2 below:

Table 2

DISCUSSION

Our study supports our assumption that wearing facial PPE reduces staff understanding and conventional communication in simulated ITU and theatre settings. Despite the small sample size, results suggest that the louder background environments such as theatre produced the most pronounced (statistically significant) effect on speech comprehension. The excess noise generated in such environments can be attributed to many factors (aptly summarised in the paper by Kam et al, 1994[19]) that range from equipment and type of surgical/anaesthetic activity to numbers of personnel and consequent raised voice levels. We have demonstrated that wearing PPE will complicate communication further. In this study, speech comprehension wearing PPE within the theatre simulated environment (70dB) was significantly worse than wearing no PPE. Raising of voice in a theatre simulated environment when wearing PPE caused a significant improvement of BKB scores to a level that was not significantly different from scores when not wearing PPE.

Despite the observed variance in SNR, BKB scores were still generally poorer with PPE which may indicate a difficulty in understanding un-related to volume or SNR.

Background levels of noise in our simulation were derived from environmental recordings that correlated with prior studies where noise levels in the operating theatre exceed World Health Organisation recommendations[20]. It has been suggested that noise masking speech often results in surgeons having to repeat themselves and consequently, it takes longer for other members of the team to respond or assist[20]. Research exists on background noise and its impact on adherence of staff to the WHO surgical safety checklist, but outside of calls for quiet during the 'Time Out', perceptions of barriers to communication during the rest of the procedure is less well investigated[21].

We have confirmed anecdotal reports that communication difficulties due to PPE will impact on healthcare workers. Safety of healthcare staff is paramount and the ongoing use of PPE as the initial coivd-19 pandemic wanes is likely to continue. Therefore we anticipate that these communication issues will be exacerbated, particularly in operating theatres, where anaesthetists, operating department practionners, nurses and surgeons will wear AGP PPE for prolonged durations once some longer procedures and elective operating recommences. Interpretation of our findings should be in light of the fact that we simulated background noise and the study candidates were healthcare staff without hearing impairment who regularly work together, which may mean our results would not be reproduced "in the field". Clinical situations regularly involve a variety of shift-working healthcare providers and the additional cognitive load of actually treating patients. Nonetheless, our simulation used validated speech testing and we are unaware of any other studies which have assessed communication difficulties with Covid-19 PPE to this standard.

The importance of speech understanding for achieving success on shared objectives has been extensively researched in military and industrial occupational settings, with need to communicate with co-workers in noisy backgrounds regularly resulting in the removal of protective equipment[22]. There are obvious and immediate implications in theatre e.g. safety compromised, wrong instrument being selected or inadequate delivery of the WHO checklist.

Studies have suggested that as much as 12 dB SNR is required for speech understanding in the presence of background noise levels up to 110 dB SPL[23] but thresholds for adults have also been recorded with ratios close to 0 dB or <0 dB[24].

4

One impact of PPE we have not discussed is the removal of visual cues to communication. Various studies have demonstrated that visual features strongly affect the perception of speech[17]. This contribution is most pronounced in noisy environments where the intelligibility of audio-only speech is quickly degraded[25].

We recommend that regular reminders to speak up and acknowledge communication difficulties at key times during ITU ward rounds and theatre pre-operative briefs may help staff to improve communication whilst wearing PPE. Some specialty guidelines have recommended wearing photographs of staff members over their PPE or writing their name and roles on the apron[26]. Some centres have advocated communicating with hand signals, transparent masks or hoods[17], white-boards or even two way radio/walkie-talkies in cellophane bags where possible[27]. Others have suggested possible wireless microphone and speaker systems incorporated into PPE[28](micrashell) or even already provided PPE designs with voice amplification solutions[29] that utilise mobile phone technology. For modern multidisciplinary teams, this may not be a suitable solution when there needs to be multidirectional conversation and information exchange. Solutions like CARDMEDIC (a free to use collection of communication flashcards) have been designed to help healthcare workers speak to patients despite PPE, but we are unaware of any similar device specific to communication between healthcare workers i.e. in theatre (https://www.cardmedic.com/)[30].

The drawbacks in this study were principally the small sample size that did not allow us to measure an effect size. In addition the study was performed in one hospital site only and representative environmental noise levels could differ across different hospital sites. We welcome the opportunity to work with other teams across the UK and further afield in testing, trialling and simulation, as well as supporting qualitative work for any PPE communication solutions for future working practices.

CONCLUSIONS

Where attempts to deliberately raise voice or shout through PPE were simulated, understanding significantly improved as expected. Raising of voice for prolonged periods may lead to issues with voice strain and abuse, in addition to frustration or miscommunication. We hope that now communication difficulties have been demonstrated, this will help drive attempts to mitigate these issues for healthcare workers emerging from the Covid-19 pandemic. We hope our findings can inform the ongoing use of PPE once elective healthcare provision is restarted and for the future, facing whatever pandemics may lie ahead.

All authors declare no conflicts of interest, financial or otherwise.

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