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Speech Understanding Using Surgical Masks: A Problem in Health Care?

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Abstract

Background: Successful communication is necessary in health-care environments. Yet the presence of noise in hospitals, operating rooms, and dental offices may have a deleterious effect on health-care personnel and patients understanding messages accurately. The presence of a surgical mask and hearing loss may further affect speech perception.

Purpose: To evaluate whether a surgical mask had an effect on speech understanding for listeners with normal hearing and hearing impairment when speech stimuli were administered in the presence or absence of dental office noise.

Research Design: Participants were assigned to one of two groups based on hearing sensitivity in this quasi-experimental, cross-sectional study.

Study Sample: A total of 31 adults participated in this study (1 talker, 15 listeners with normal hearing, and 15 with hearing impairment). The normal hearing group had thresholds of 25 dB HL or better at the octave frequencies from 250 through 8000 Hz while the hearing loss group had varying degrees and configurations of hearing loss with thresholds equal to or poorer than 25 dB HL for the same octave frequencies.

Data Collection and Analysis: Selected lists from the Connected Speech Test (CST) were digitally recorded with and without a surgical mask present and then presented to the listeners in four conditions: without a mask in quiet, without a mask in noise, with a mask in quiet, and with a mask in noise.

Results: A significant difference was found in the spectral analyses of the speech stimuli with and without the mask. The presence of a surgical mask, however, did not have a detrimental effect on speech understanding in either the normal-hearing or hearing-impaired groups. The dental office noise did have a significant effect on speech understanding for both groups.

Conclusions: These findings suggest that the presence of a surgical mask did not negatively affect speech understanding. However, the presence of noise did have a deleterious effect on speech perception and warrants further attention in health-care environments.

Key Words: Background noise, speech perception, surgical masks

Abbreviations: MCL = most comfortable loudness; rau = rationalized arsine units; SNR = signal-to-noise ratio

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Sumario

Antecedentes: La comunicación exitosa es necesaria en ambientes de atención en salud. Sin embargo, la presencia de ruido en hospitales, quirófanos y en consultorios dentales puede tener efectos dañinos sobre el personal de salud e interfiere en los pacientes con la captación precisa de los mensajes. La presencia de una mascarilla quirúrgica y de una hipoacusia puede afectar aún más la percepción del lenguaje.

Propósito: Evaluar si la mascarilla quirúrgica tuvo un efecto sobre la comprensión del lenguaje en sujetos con audición normal y con hipoacusia, cuando los estímulos se presentaron en presencia y en ausencia de ruido en el consultorio dental.

Diseño de la Investigación: Los participantes fueron asignados a uno de dos grupos con base en su sensibilidad auditiva, en este estudio de corte transversal cuasi-experimental.

Muestra del Estudio: Un total de 31 adultos participaron en este estudio (1 vocero, 15 con audición normal y 15 con hipoacusia). El grupo con audición normal tenían umbrales de 25 dB o mejores en las bandas de octava de 250 a 8000 Hz, mientras que el grupo con hipoacusia tenían grados variables de pérdida auditiva y de configuración con umbrales iguales o por debajo de 25 dB HL, para las mismas bandas de octava.

Recolección y Análisis de los Datos: Se grabaron digitalmente listas seleccionadas de la Prueba de Lenguaje Conectado (CST) con y si el uso de una mascarilla quirúrgica, que luego fueron presentadas a los sujetos en cuatro condiciones: sin mascarilla en silencio, sin mascarilla en ruido, con mascarilla en silencio y con mascarilla en ruido.

Resultados: Se encontró una diferencia significativa en el análisis espectral de los estímulos lingüísticos con y sin mascarilla. La presencia de la mascarilla quirúrgica, sin embargo, no tuvo un efecto negativo sobre la comprensión del lenguaje, ni en los sujetos normoyentes ni en los hipoacúsicos. El ruido del consultorio dental sí tuvo un efecto significativo en la compresión del lenguaje en ambos grupos.

Conclusiones: Estos hallazgos sugieren que la presencia de una mascarilla quirúrgica no afectó negativamente la comprensión del lenguaje. Sin embargo, la presencia de ruido tuvo un efecto negativo sobre dicha percepción y exige más atención en los ambientes de cuidados de salud.

Palabras Clave: Ruido de fondo, percepción del lenguaje, mascarilla quirúrgicas

Abreviaturas: MCL = nivel confortable de sonoridad; rau = unidades racionalizadas de arcoseno; SNR = tasa señal-ruido

Successful communication is an essential component of health care, and it is fundamental to ensuring that procedures are performed effectively, that health-care personnel understand messages accurately and appropriately, and that patients' concerns are adequately expressed to their health-care providers. In many health-care facilities, such as operating rooms and dental offices, communication is often hindered due to varying levels of background noise that can affect the interpretation of various messages. In addition, health-care personnel often wear surgical masks while performing procedures. These masks form a physical barrier between the sender of a message and the intended recipient. This barrier not only affects access to visual cues but very possibly may degrade the auditory signal as well. Because over 31 million Americans have hearing impairment (Kochkin, 2005), successful communication could be negatively impacted when a surgical mask is used. The focus of this study was to examine what effect a surgical mask may have on speech understanding.

While a direct study of communication through surgical masks has not been completed to date, the literature demonstrates that there is a need for this type of investigation. There is considerable evidence showing that when auditory information is degraded, there is a greater need for visual cues to make up for this diminished signal (Kawase et al, 2005). When background noise is present, understanding speech is noticeably more difficult, making visual cues essential for accurate speech recognition. Unfortunately, when surgical masks are present, visual cues are not. Champion and Holt (2000) found that nearly two-thirds of the children with hearing impairment in their study had difficulty communicating with the dentist while the dentist was wearing a mask and in the presence of music and traffic noise in the office. It is likely that the same difficulties apply to adults with hearing impairment as well.

The effects of noise on performance and communication also appear to be a common concern in health care (Hodge and Thompson, 1990; Murthy et al, 1995; Champion and Holt, 2000; Moelker et al, 2004; Moorthy et al, 2004; Tijunelis et al, 2005; Perillo, 2006; Sampaio Fernandes et al, 2006; West and Busch-Vishniac, 2006). Overhead speaker pages, announcements, patient monitors, internal and external pedestrian traffic, doors opening and closing, air conditioners, heaters, constant communication, and the use of various manual and electric equipment contribute to this excessive noise. Several researchers have measured noise levels in various health-care settings. In a large urban emergency department, Tijunelis et al (2005) obtained time-weighted average recordings at 43 dBA with a dosimeter placed on a wall (12 hours) and 52.9 dBA with a dosimeter placed on a volunteer medical student (8 hours) with various brief noise sources exceeding 90 dBA during these hours. Murthy et al (1995) obtained noise levels of 77.32 dBA in their operating rooms. West and Busch-Vishniac (2006) found that daytime noise levels in modern hospitals had risen from 57 dB SPL in 1960 to 72 dB SPL, and Perillo (2006) found that evening noise had risen from 42 to 60 dB SPL. Finally, Sampaio Fernandes et al (2006) measured noise levels in various acoustic environments within a dental school and found levels between 60 and 99 dBA.

Interestingly, the Environmental Protection Agency (EPA) recommends that hospital settings have equivalent sound levels of 45 dBA or less to minimize activity interference and 70 dBA or less to protect against noise-induced hearing loss (EPA, 1974). In many of the above studies, one or both of the EPA recommendations were exceeded. Thus, it is clear that effective communication is very likely to be compromised in medical and dental procedures. Furthermore, Firth-Cozens (2004) states, "there is evidence from a variety of sources that communications between members of healthcare teams emerge as a key factor in poor care and are especially apparent where medical errors occur" (p. 327). Although Firth-Cozens (2004) did not specifically mention the effect of noise pollution on possible miscommunication, the reduction of noise would probably improve communication.

In the field of dentistry, hearing protection and communication interference have been discussed in light of potentially hazardous noise. For example, when a group of 137 dentists and 80 physicians were compared, Zubick et al (1980) found that dentists had significantly greater high-frequency hearing loss than the physicians, leading to a possible relationship between hearing loss and the use of high speed dental tools. However, according to Hyson (2002), a definitive relationship between high speed dental tools and hearing thresholds has been difficult to establish with the existing literature. Though noise levels from dental tools are high, hearing damage risk is believed to be low and well within the daily maximum allowable exposure levels because of intermittent use of these instruments (Wilson et al, 1990; Sorainen and Rytkönen, 2002; Sampaio Fernandes et al, 2006). However, any noise at all between and during dental procedures is still likely to impact speech perception negatively. For example, Wilson et al (1990) conducted speech understanding measures with nonsense syllables and common sentences in the presence of dental drill noise. High noise levels resulted in an average understanding of 18–48% of nonsense syllables and 52–90% of common sentences. Although these results do not directly relate to the effect of surgical masks on communication, they indicate that high noise levels have a negative effect on speech recognition. It is possible that the presence of a surgical mask (especially in noise) could also degrade the speech signal and decrease speech recognition performance.

Every dental clinic has a different setup; procedures are either conducted in an enclosed office with few personnel or in a more open office setting with adjacent units with multiple personnel. While a dentist or related practitioner may not be in the habit of speaking while using noisy tools, in an open office setting there may be nearby procedures being conducted, ongoing conversations, and pedestrian traffic. These sources of noise may indeed affect speech recognition.

In addition to their patients, health-care personnel may also have hearing impairment (Fabry, 1993; Carroll 2003; Dietrich, 2005; Yoder and Pratt, 2005). Advances such as amplified stethoscopes have been made to accommodate the physician with hearing loss (Fabry, 1993; Morris, 2001; Rennert et al, 2004). The development of such stethoscopes supports the notion that professionals with hearing impairment often experience difficulties in their daily routines. For professionals with hearing impairment, the combination of noise and lack of visual cues could cause considerable difficulty in understanding. If, in addition to these factors, the material of the mask acts as a sound barrier, then speech understanding may be extremely difficult. Therefore, although some advances have been made in accommodating health-care professionals with hearing loss, if surgical masks are found to contribute to communication problems with or without noise, then changes in their design may also be necessary to ensure accurate communication.

Although there is little literature published on this topic, the need for further research examining communication in hospitals, operating rooms, and dental offices exists. Miscommunications can cause mistakes that can lead to compromised patient care. The purpose of this study was to investigate the effects of a surgical mask on the speech perception abilities of individuals with normal hearing and hearing impairment in quiet and noise conditions. For this study, recorded dental office noise was employed.

METHOD

Participants

A total of 31 adults participated in this study (1 talker, 15 listeners with normal hearing and 15 with

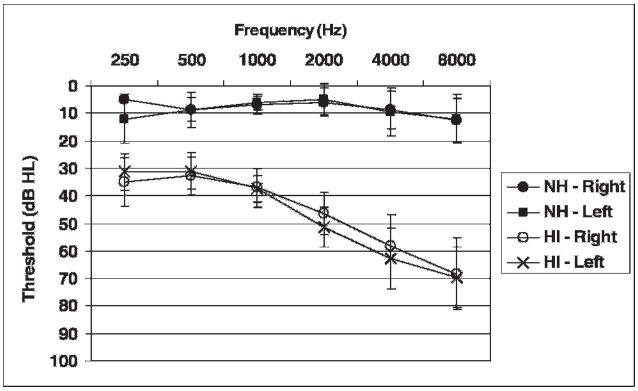


Figure 1. Mean air-conduction thresholds for the normal-hearing and hearing-impaired groups with error bars reflecting ±1 standard deviation around the mean. NH = normal hearing; HI = hearing impaired.

hearing impairment). All participants had normal middle ear function bilaterally as evidenced by normal tympanograms (i.e., normal tympanometric peak pressure, ear canal volume, static admittance, and tympanometric width using screening normative data from Roup et al (1998). Figure 1 shows the pure-tone thresholds for both groups. The listeners with normal hearing (aged 22 to 54 years; M = 28) had thresholds of 25 dB HL or better at the octave frequencies from 250 through 8000 Hz while those with hearing loss (aged 23 to 75 years; M = 58) had varying degrees and configurations of hearing loss with thresholds equal to or poorer than 25 dB HL for the same octave frequencies. The mean pure-tone average (PTA; 500, 1000, and 2000 Hz) for the listeners with hearing loss was 39.28 dB HL. Of the 15 listeners with hearing loss, six wore bilateral hearing aids with 1–10 yr of experience, one wore a hearing aid unilaterally, and the remaining eight participants did not wear hearing aids at all. The talker was a 48-year-old male with normal speech and language and a standard American dialect.

Stimuli and Instrumentation

There are no known standardized recordings of speech stimuli using a surgical mask. Therefore, for the purposes of this study, a digital recording of a subset of the stimuli from the Connected Speech Test (CST; Cox et al, 1988) was made by the adult male talker. Given that monitored-live-voice presentation of the stimuli would not have been reliable, this novel recording was necessary in order to provide consistent stimuli with and without the mask. It is possible that this rerecording could have affected the previous validation of the CST. However, because the recordings were used simply as a stimulus and the results were not compared to other subjects, test conditions, or previous studies, it is expected that this rerecording did not jeopardize any standardization data of the CST.

The lists from the CST are equivalent and of equal intelligibility (Cox et al, 1988). Eight lists of the CST were randomly selected for recording. Each list contained ten sentences of related context, with a total of 25 key words to be scored. The talker recorded the following eight lists of the CST with and without wearing a surgical mask: (1) Lists 1, 2, 3, 4, 25, 26, 27, and 28 read and recorded without a mask and (2) Lists 33, 34, 35, 36, 41, 42, 43, and 44 read and recorded with a mask present. The mask was a standard surgical type made of expandable fabric frequently used in hospitals and dental offices.

All stimulus recordings were made in a sound-treated booth meeting ANSI S3.1-1999 (American National Standards Institute [ANSI], 2008). The recordings were produced by the male talker who was experienced in producing acoustically controlled speech stimuli. The samples were recorded via a Shure SM93 microphone positioned approximately 12 inches from the speaker who was seated in the sound booth facing the booth window. The leads from the microphone were fed directly to a digital audio recorder (Marantz Professional HD/CD Digital Recorder [CDR 420]) positioned outside of the booth with the VU display visible to the speaker through the booth window. A recording bit rate of 128 kpbs and 48 kHz sample frequency were used, and the samples were saved onto an IBM microdrive (1GB CF+ Type II PC card) for easy transfer to a desktop computer for editing. To provide a consistent target for intensity, a marker was placed on the VU display of the digital recorder at a midrange setting, which had been predetermined to result in non-peak-clipped recordings and low noise levels. Also, while the speech stimuli were being recorded the individual productions were monitored for rate, intensity (i.e., peak clipping, stress), and vocal quality (i.e., fry, hoarseness) by two listeners positioned outside the booth. The listeners (experienced professionals in communication disorders) monitored the productions via headphones and provided feedback to the speaker regarding the acceptability of each production. A stopwatch was used to provide a general guide for whether the target-range of 3.0–3. 5 syllables per second (syl/sec) had been achieved. The sound files were edited using Adobe Audition (Adobe Systems Incorporated, version 2.0).

Once the stimulus recording was complete, the noise from a dental hand drill was recorded in a dental office in the middle of the morning (at about 10:00 am). The microphone was placed on the side of the patient's chair in close proximity to the patient's head (approximately three to six inches from the head). The microphone was near the hand piece at all times, and the distance only varied if close proximity hindered the actions of the dentist while performing his procedures. The noise from the hand piece and suction was the primary input to the recording; no outside noise or noise from the front office was included in the recording.

Noise from the hand piece was recorded using the Shure BG 1.0 microphone and the Marantz Professional HD/CD Recorder (CDR 420) used in the stimulus recordings. Adobe Audition (Adobe Systems Incorporated, version 2.0) was used to analyze the noise sample. The portions of the noise recording whose overall intensity was above the recommended level of noise of 45 dB SPL (EPA, 1974) were edited and looped to create a one-hour sample of noise.

Procedure

Prior to data collection, all participants signed an informed consent form approved by the University of Memphis Institutional Review Board for participation in this study, and basic ethical considerations were taken for the protection of the research participants throughout the project. Pure tone thresholds were measured for all listeners using a GSI 61 audiometer meeting ANSI S3.6-2004 (ANSI, 2004) and standard audiometric procedures. Middle ear function was screened using a GSI 38 AutoTymp calibrated to ANSI S3.39-1987 (ANSI, 2007). Once hearing sensitivity and middle ear function was verified, the listeners were seated in the same sound-treated room that was used for the recording of the stimuli. Each recording was presented to the listeners through a GSI 61 audiometer at a comfortable level through a Bose loudspeaker 1 m away at 0° azimuth. Both groups of research participants listened to the stimuli in the following four conditions:

Condition 1: Lists 1, 2, 3, and 4; recorded without a mask, presented in quiet
Condition 2: Lists 25, 26, 27, and 28; recorded without a mask, presented in noise
Condition 3: Lists 33, 34, 35, and 36; recorded with a mask, presented in quiet
Condition 4: Lists 41, 42, 43, and 44; recorded with a mask, presented in noise

All lists and conditions were presented randomly to prevent order effects. In the noise conditions, the recorded dental office noise was presented through the same speaker as the speech stimuli at 0° azimuth to simulate face-to-face communication.

The speech stimuli were presented at the most comfortable loudness (MCL) level for the listeners who were hearing impaired. MCLs were used to be sure that the presentation level would be audible to them based on their varying levels of hearing loss. MCLs were obtained using a modified version of the procedure outlined in the Contour Test (Cox et al, 1997). Using live voice, research participants were asked to judge the loudness of the speech signal (connected discourse) by choosing among seven categories of loudness. The goal was for the listener to judge the speech as "comfortable" (category 4). MCLs ranged from 60 to 80 dB HL (three listeners judged MCL at 60 dB HL, 1 at 65 dB HL, 7 at 70 dB HL, 2 at 75 dB HL, and 2 at 80 dB HL).

For listeners with normal hearing, the presentation level of the speech stimuli was at 60 dB HL (selected as the low end of the range of MCLs measured by those with hearing loss). Although 60 dB HL is a fairly high presentation level, we wanted to set the levels somewhat comparably between the two groups. For both groups, the speech stimuli were presented at a +5 SNR (signal-to-noise ratio) relative to the respective stimulus presentation levels. This SNR was selected based on the levels used in the original development of the CST (Cox et al, 1988).

All research participants listened to each of the four recordings and conditions and repeated what they heard. Scoring procedures for the CST were fairly strict in that the listeners' responses to the stimuli were accepted as correct only if all words in each sentence were repeated correctly, that is, exactly as the stimulus was presented.

Interjudge Scoring Reliability

Digital audio recordings were made of the listeners' responses for reliability purposes. To ensure accuracy in scoring the talk-back responses from the participants, interjudge scoring reliability was conducted on 30% of the data (15% normal hearing, 15% hearing impaired), using the following formula: (agreements / [agreements + disagreements]) × 100%. Interjudge scoring reliability was 98%.

RESULTS

The purpose of this experiment was to determine whether speech stimuli recorded with and without a surgical mask in the presence or absence of dental office noise had an effect on speech understanding for listeners with normal hearing and hearing loss. The stimuli were presented randomly in four conditions: without a mask in quiet, without a mask in noise, with a mask in quiet, and with a mask in noise.

Spectral Analysis of Stimuli

Using Adobe Audition (Adobe Systems Incorporated, version 2.0), all of the lists were edited by removing the pauses between sentences, and then the total root mean square (RMS) power was measured for the average speech spectra for each condition (with and without the mask) and the noise. The total RMS power values for each of the eight lists recorded without the

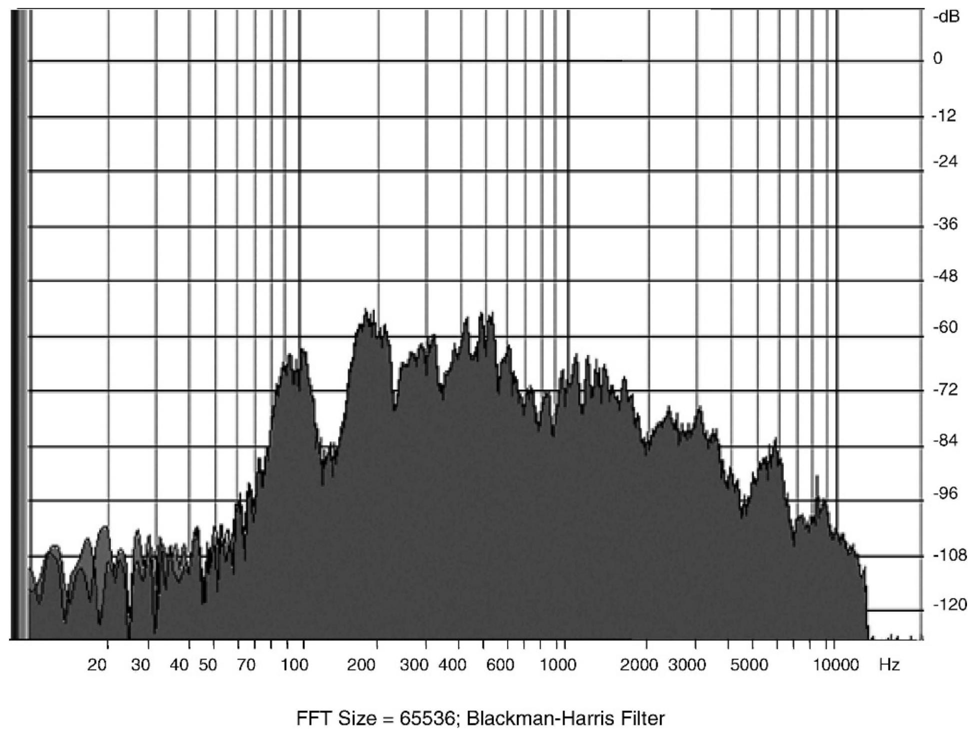


Figure 2. Spectral analysis of CST passages recorded without a surgical mask.

surgical mask were averaged and compared to the mean total RMS power values for the eight lists recorded with the surgical mask. The total RMS power for the lists recorded without the surgical mask was −39.52 dB SPL and with the surgical mask was −39.31 dB SPL. The dB values are relative to 0 dBFS (full-scale), which is the maximum possible level for the 16-bit digitizer used in this study of 96 dB SPL. A two-tailed t-test with equal variances assumed indicated that the total RMS power for the speech spectra yielded a significant difference ($t = -2.297$, df = 14, $p = 0.038$) between the two spectra. Figures 2 and 3 show the spectral analysis for the lists recorded without and with a mask, respectively. The spectral analysis of the dental office noise revealed the total RMS power to be −36.4 dB SPL (Figure 4).

Speech Perception Results

All percent correct scores on the CST were converted to rationalized arcsine units (rau; Studebaker, 1985) for statistical analysis. A linear regression analysis was conducted between the two groups of listeners (between subjects factor; normal hearing and hearing impaired), the two recording conditions (within subjects factor; with and without a surgical mask), and the two listening conditions (within subjects factor; quiet and noise). This multivariate procedure provides analysis of variance for multiple dependent variables (e.g., condition and mask) by the fixed factor of group. Statistically significant main effects were found for group (F [1,28] = 8.47, $p < 0.007$), condition (F [1,28] = 10.17, $p = 0.004$), and mask (F [1,28] = 60.86, $p < .000$). There were no significant interaction effects. The overall mean score (in percent correct and rau) for the normal-hearing group was significantly better than that for the hearing-impaired group. Figure 5 displays the mean percent scores between groups and across conditions indicating that the mean scores for the normal-hearing group were significantly higher than those obtained for the hearing-impaired group, as expected.

Listeners with Normal Hearing

The speech perception scores with the mask present (98.77%) for the listeners with normal hearing were significantly better than their scores without the mask (97.83%). This comparison is displayed in the left portion of Figure 6. A statistically significant difference was measured between the means with and without the mask. However, given that this difference was less than 1% (0.94%), this finding is not considered to be clinically significant. This finding was unexpected as we anticipated that the presence of the mask would actually result in a decrease in scores.

Post hoc Tukey comparisons revealed that the mean speech perception scores in quiet (99.23%) were significantly better than those for the noise condition (97.37%) for the normal-hearing group ($p < 0.05$). The left portion of Figure 7 displays this comparison. Again, although the difference between these mean

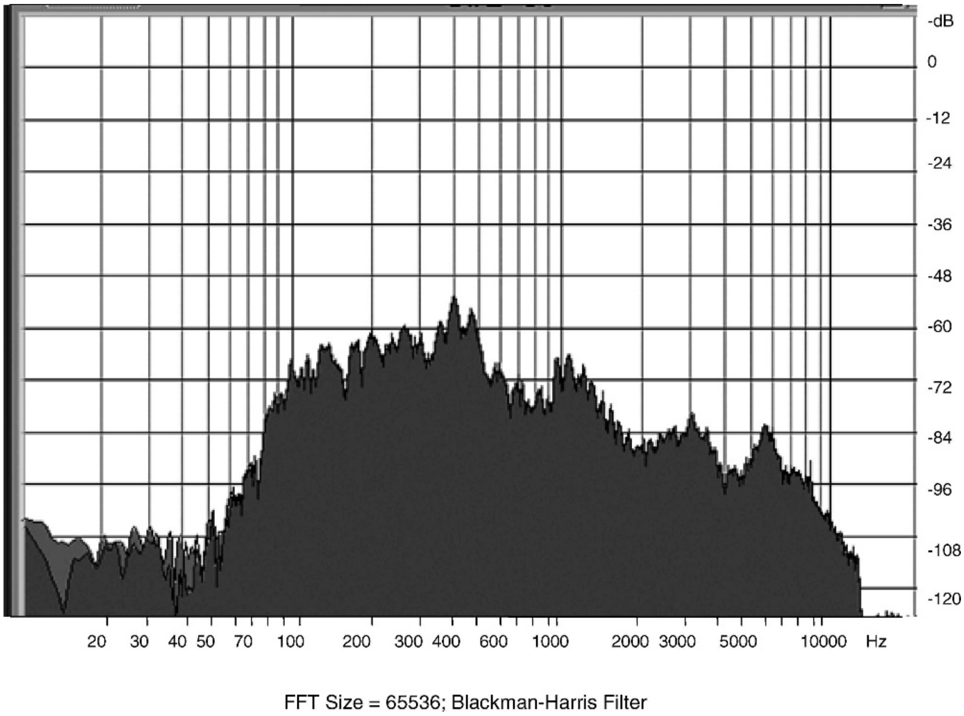


Figure 3. Spectral analysis of CST passages recorded with a surgical mask.

scores was statistically significant, the difference was so minimal (1.87%) that is likely not a clinically significant difference. Nonetheless, this trend in the results agreed with our expectation that listeners would perform better in quiet than in noise regardless of whether the mask was present.

Listeners with Hearing Loss

The effect of the recording condition (mask) was also significant for the hearing-impaired group, and again the scores with the mask present (93.20%) were better than those without the mask (92.13%). With respect to

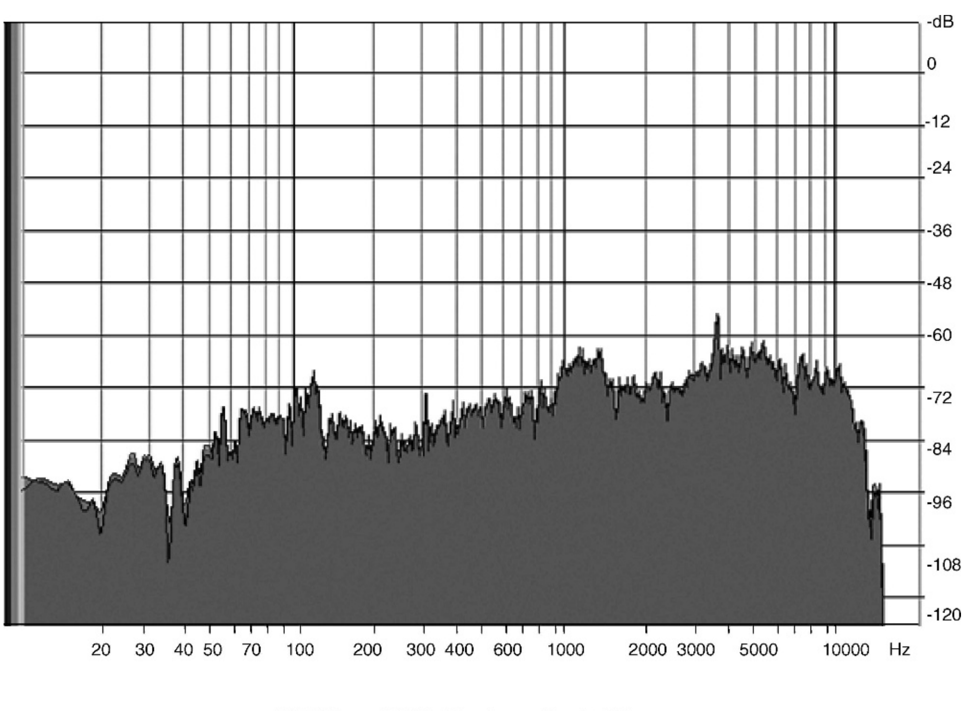
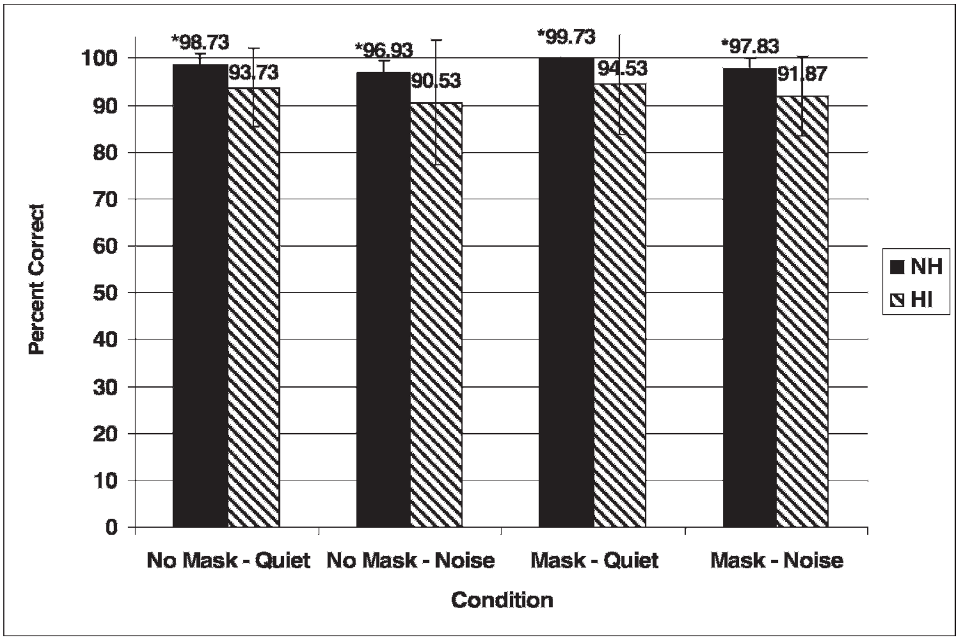


Figure 4. Spectral analysis of the dental office noise.



*p<0.007

Figure 5. Mean speech perception scores for each group in each condition. Error bars reflect ±1 standard deviation around the mean. NH = normal hearing; HI = hearing impaired. *p < 0.007.

condition, post hoc Tukey comparisons revealed that the mean speech perception scores in quiet (94.13%) were significantly better than those for the noise condition (91.20%). The difference between the mean scores in quiet and in noise for the hearing-impaired group was larger (2.93%) than for the normal-hearing group. These findings confirmed our hypothesis that the listeners with hearing loss would have more difficulty in noise than those with normal hearing. The right side of Figure 6 displays the results for the hearing-impaired group with and without the mask, and the right side of Figure 7 shows their speech perception scores in quiet and in noise.

DISCUSSION

The purpose of this study was to determine whether the presence of a surgical mask and dental office noise had an effect on speech understanding for listeners with normal hearing and hearing loss. The

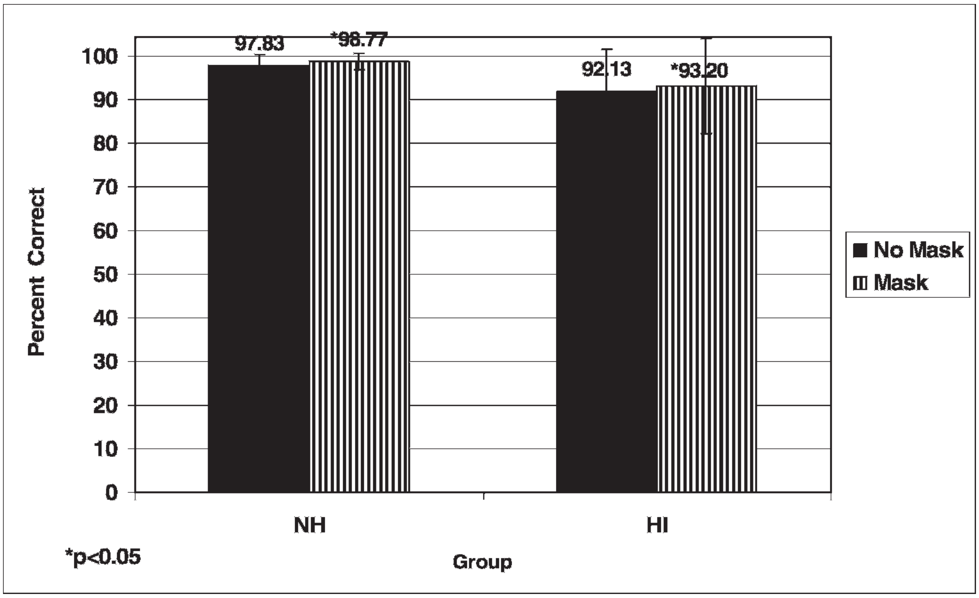


Figure 6. Mean speech perception scores for each group with and without the mask present. Error bars reflect ±1 standard deviation around the mean. NH = normal hearing; HI = hearing impaired.

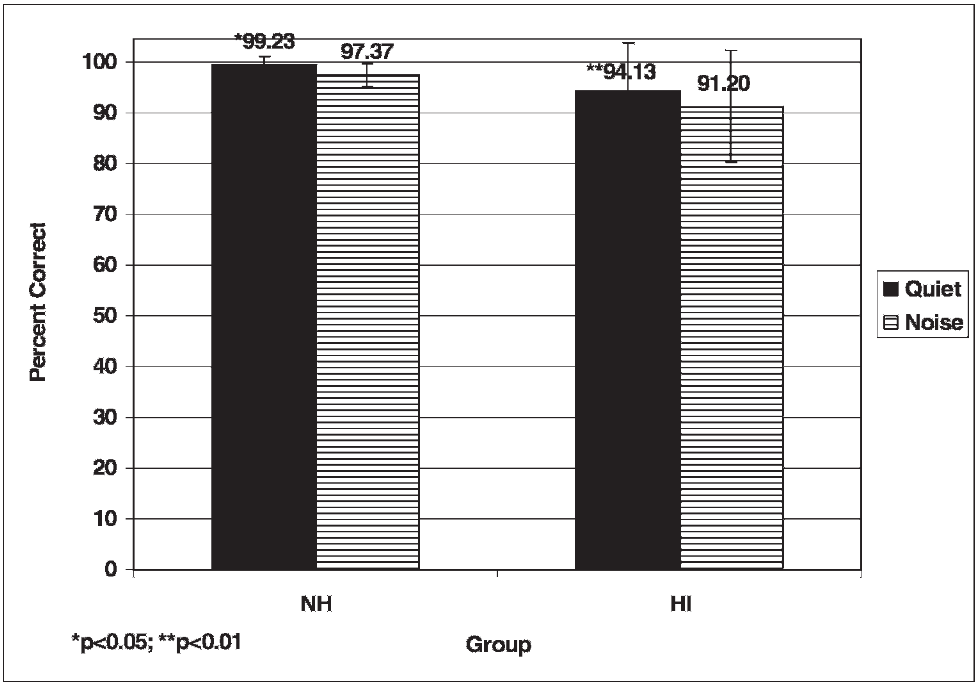


Figure 7. Mean speech perception scores for each group in quiet and in noise. Error bars reflect ±1 standard deviation around the mean. NH = normal hearing; HI = hearing impaired.

significant main effect for group suggested that listeners with hearing loss had more difficulty with the speech perception task, especially in noise, than the listeners with normal hearing. However, as stated earlier, the difference measured was extremely small. This group difference could be related not only to the effect of hearing loss but also to the mean difference in age across the groups.

Most interestingly, the measured effects of the surgical mask did not produce the anticipated degradation on speech perception with either population as hypothesized at the beginning of this study. It was hypothesized that the presence of the mask would degrade the signal and decrease speech perception ability for both groups. What we found, however, was actually the opposite effect for both groups who actually had better speech perception scores when the mask was present. Although this finding was statistically significant, the difference in the mean scores was considerably small, which was likely not clinically significant. Therefore, it can be concluded that, from a clinical perspective, the presence of a surgical mask did not have a detrimental effect on either group's speech understanding. It should be noted that this hearing-impaired group had PTAs averaging about 40 dB HL. It is possible that listeners with greater degrees of hearing loss may have more difficulty with the mask present as reliance on visual cues increases.

Noise had a statistically significant effect on speech perception for both groups of listeners. The deleterious effect of noise on speech understanding is in agreement with previous studies that examined physicians' and dentists' abilities to hear in their professional environments (Moorthy et al, 2004, Wilson et al, 1990). Thus, regardless of whether a surgical mask is present, noise had a negative effect on speech understanding; this negative effect (although small) was worse with the listeners who were hearing impaired.

There are several possible reasons why we were unable to measure an effect of the surgical mask on speech perception. First, the talker who recorded the speech stimuli used in this study was a trained professional in radio broadcasting. Because of this background, he possessed an extremely articulate and clear manner of speaking. This talker was selected because he possessed these capabilities, but in retrospect, if we had used a talker with more casual speech production, we might have measured more of an effect of the mask. Second, in noisy situations, speakers often experience the Lombard effect and naturally increase the sound pressure level of their voices in the presence of background noise, often resulting in a shift of the speech spectrum higher in frequency. Because we chose to make recordings of the stimuli in a quiet background, we were not able to observe any of these effects and how they may have interacted in the presence of a surgical mask.

Third, all listening experiments were conducted in a controlled sound-treated environment, which made it a somewhat unrealistic listening situation with regard to variation in speech and noise levels, visual distractions, and so on. Again, we chose a sound-treated room because we wanted to have control over many of the variables being measured. Perhaps with a more natural talker and variable noise levels, different results would be obtained. Future research may explore these possibilities. In addition, further research could incorporate noise from an operating room and examine the effects of the mask when visual cues are allowed during testing.

SUMMARY AND CONCLUSIONS

Despite the statistically significant difference in the spectral analyses of the speech stimuli with and without the mask, the presence of a surgical mask did not have a detrimental effect on speech understanding in either the normal hearing or hearing-impaired groups in this study. However, the dental office noise did have a small, yet significant, effect on speech understanding for both groups. These findings suggested that the presence of noise in health-care facilities may be of greater concern than communicating through surgical masks. What is currently unknown is at what severity of hearing loss a surgical mask will have an effect on speech understanding, if any. Additional research is necessary to help further investigate these issues.

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REFERENCES

American National Standards Institute (ANSI). (2007) *Specifications for Instruments to Measure Aural Acoustic Impedance and Admittance (Aural Acoustic Immittance).* (ANSI S3.39-1987). New York: American National Standards Institute.

American National Standards Institute (ANSI). (2008) *Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms.* (ANSI S3.1-1999). New York: American National Standards Institute.

American National Standards Institute (ANSI). (2004) *Specifications for Audiometers.* (ANSI S3.6-2004). New York: American National Standards Institute.

Carroll SM. (2003) Lip-reading translating for non-vocal ventilated patients. *J Assoc Med Prof Hear Losses* 1(2):http://www.amphl.org/articles/carroll2003.pdf.

Champion J, Holt R. (2000) Dental care for children and young people who have hearing impairment. *Br Dent J* 189:155–159.

Cox RM, Alexander GC, Gilmore C. (1988) Development of the connected speech test (CST). *Ear Hear* 8(5 Suppl.):119S–126S.

Cox RM, Alexander GC, Taylor IM, Gray GA. (1997) The contour test of loudness perception. *Ear Hear* 18:388–400.

Dietrich S. (2005) Road test: an FM system in a dental office/educational setting. *Hear Rev* 12:38–42.

Environmental Protection Agency (EPA). (1974) *Information on the Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*. Washington, DC: U.S. Government Printing Office. http://www.nonoise.org/library/levels74/levels74.htm.

Fabry DA. (1993) Clinical and communication access through amplification for a medical student with severe hearing loss: case report. *J Am Acad Audiol* 4:426–431.

Firth-Cozens J. (2004) Why communication fails in the operating room. *Qual Saf Health Care* 13:327.

Hodge B, Thompson JF. (1990) Noise pollution in the operating theatre. *Lancet* 335:891–894.

Hyson JM. (2002) The air turbine and hearing loss. *J Am Dent Assoc* 133:1639–1642.

Kawase T, Yamaguchi K, Ogawa T, Suzuki K, Suzuki M, Itoh M, Kobayashi T, Fujii T. (2005) Recruitment of fusiform face area associated with listening to degraded speech sounds in auditory—visual speech perception: a PET study. *Neuro Lett* 382:254–258.

Kochkin S. (2005) MarkeTrak VII: hearing loss population tops 31 million. *Hear Rev* 12:16–29.

Moelker A, Maas RAJJ, Pattynama PMT. (2004) Verbal communication in the MR environment: effect of MR system acoustic noise on speech understanding. *Radiology* 232:107–113.

Moorthy K, Munz Y, Undre S, Darzi A. (2004) Objective evaluation of the effect of noise on the performance of a complex laparoscopic task. *Surgery* 136:25–30.

Morris R. (2001). *How to Cope with Scopes*. Association of Medical Professionals with Hearing Losses. http://www.amphl.org/articles/morris2001.html.

Murthy VSSN, Malhotra SK, Bala I, Raghunathan M. (1995) Detrimental effect of noise on anesthetists. *Can J Anaesth* 42: 608–611.

Perillo D. (2006) Rise in hospital noise. *Adv Speech Lang Pathol Audiol* 16(4):21.

Rennert NJ, Morris R, Barrere CC. (2004) How to cope with scopes: stethoscope selection and use with hearing aids and CIs. *Hear Rev* 11:34–75.

Roup CM, Wiley TW, Sfady SH, Stoppenbach DT. (1998) Tympanometric screening norms for adults. *Am J Audiol* 7:55–60.

Sampaio Fernandes JC, Carvalho APO, Gallas M, Vaz P, Matos PA. (2006) Noise levels in dental schools. *Eur J Dent Educ* 10:32–37.

Sorainen E, Rytkönen E. (2002) Noise level and ultrasound spectra during burring. *Clin Oral Investig* 6:133–136.

Studebaker GA. (1985) A “rationalized” arcsine transform. *J Speech Hear Res* 28:455–462.

Tijunelis MA, Fitzsullivan E, Henderson SO. (2005) Noise in the ED. *Am J Emerg Med* 23: 332–335.

West JE, Busch-Vishniac IJ. (2006) What do we know about noise in hospitals? *Acoust Today* 2(1):44–45.

Wilson CE, Vaidyanathan TK, Cinotti WR, Cohen SM, Wang SJ. (1990) Hearing damage risk and communication interference in dental practice. *J Dent Res* 69: 489–493.

Yoder S, Pratt S. (2005) Audiologists who are hard-of-hearing: demographics and specific accommodation needs. Poster presented at 17th Annual American Academy of Audiology Convention, Washington, DC.

Zubick HH, Tolentino AT, Boffa J. (1980) Hearing loss and the high speed dental handpiece. *Am J Public Health* 70:633–635.