

## Proceedings of The Institute of Acoustics

### EFFECT OF NOISE, VISUAL CUES AND HEARING PROTECTION ON LIVE SPEECH COMMUNICATION.

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With the increasing awareness of the damaging effects of loud noise on hearing, many firms now provide their employees with personal hearing protection. But its use is often resisted, and one of the reasons commonly given is that hearing protectors make speech communication more difficult. This seems to contradict the present evidence (1-5) that listeners will suffer no deterioration in speech discrimination from wearing hearing protectors when the noise level is high - in fact in levels above about 85 dB(A) speech discrimination could even be improved slightly.

Hence more detailed experiments were designed to study the effect of hearing protectors on speech discrimination when worn by the listener, on the discrimination, level and frequency characteristics of speech when worn by the speaker, and on the overall effectiveness of person to person conversation, with and without visual cues (lip reading, etc) in continuous background noise. Apart from Kryter's work (1), the influence of hearing protectors on the wearer's speech has been largely ignored.

#### 1. EXPERIMENTAL PROCEDURE

Person to person articulation tests were carried out in a semi-reverberant room using the set-up shown in figure 1. One subject acted as the speaker and read aloud randomised Boothroyd isophonemic word lists (6) while wearing in turn MSA V51R earplugs, Amplivox 'Sonogard' earmuffs, or no protection, in four levels of continuous background noise from 67 dBA to 95 dBA. One list was read for each combination of noise level and protection, making 12 in all. Three subjects, one wearing earplugs, one with earmuffs and one with no protection acted as listeners and wrote down what they heard. Each subject in turn acted as speaker while the other three listened, and the session ended when all 4 had spoken.

In any one session the listeners were either required or forbidden to watch the speaker, ie, with or without visual cues. The speaker always looked at the listeners to prevent him reading unnaturally quietly to himself, but no instructions were given to him regarding voice level. The speech was recorded for later analysis with a microphone placed 0.3 m from the speaker's lips and not obstructing the listeners' views.

In all, two separate groups of 4 normally hearing male subjects participated in 4 sessions each, two session with and two without visual cues. Visual cueing order was balanced between the two groups, noise level order, and other experimental conditions were balanced between speakers within each session.

#### 2. RESULTS AND DISCUSSION

2.1 Discrimination scores Listeners' responses were scored by percentage of phonemes correctly heard. Figure 2 shows the mean results for each experimental condition.

Predictably speech discrimination decreases as noise level increases and while visual cueing has little effect on high discrimination in low noise levels, it greatly improves discrimination in the higher levels, regardless of any hearing protection worn by either listener or speaker. Visual cueing has more effect on communication than any aspect of hearing protection. In

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a noise level of 95 dBA, introducing visual cueing gave roughly the same improvement in discrimination score as an 8-10 dB reduction in background noise level, though this will vary considerably with individual speakers, listeners and conditions.

Earmuffs or earplugs worn by listeners slightly improved speech discrimination in noise levels above about 85 dBA, while below this level they reduced discrimination. This is probably because hearing protectors leave the speech-to-noise ratio effectively the same, but in attenuating loud speech and noise they reduce distortion in the ear (7) and improve discrimination, whilst in attenuating quieter speech in lower noise levels they may make some speech sounds too quiet for listeners to recognise.

The wearing of hearing protectors by the speaker degrades the speech discrimination of the listeners in all noise levels. This outweighs any improvements gained by the listeners wearing protectors.

There was little difference between earplugs and earmuffs in their effect on discrimination scores.

**2.2. Speech levels.** The speech levels for each word list was defined as the average of the maximum rms levels of the 10 words in the list. Figure 3 shows that the mean speech level increases at approximately half the rate of the background noise level. Thus for each 10 dB increase in noise the speech-to-noise ratio suffers by 5 dB and discrimination is reduced. Also when wearing hearing protectors, talkers speak 2 to 3 dB more quietly, again reducing intelligibility.

A speaker's subconscious change in voice level to compensate changes in background noise or in his own voice level is called the "Lombard reflex" and is probably a learnt response (8) aimed at maintaining the speech-to-noise ratio. But since a speaker hears his voice by bone conduction as well as air conduction his own perceived speech/noise ratio is greater than that experienced by a listener and he only partly compensates for changes in background noise level. Also when he wears hearing protection external noise is reduced but because of the bone conduction, his own voice level is hardly affected. He therefore speaks more quietly, maintaining his speech/noise ratio for himself but reducing it for other people.

Although earplugs give less attenuation than the earmuffs they affect noise levels just as much, probably because they enhance bone conduction of one's own voice ("occlusion effect").

**2.3 Speech spectra** Figure 4 shows an octave band analysis of the recorded speech. The spectrum changes with level but the curves for the three ear conditions interleave, showing that any change in speech spectrum due to speakers wearing hearing protection is that to be expected from the change in voice level alone. Speakers do not apparently compensate for any subjective change in the frequency characteristic of their voices caused by wearing hearing protectors.

This does not preclude more subtle voice changes caused by hearing protection. However there was no statistically significant difference between discrimination scores of a listening panel for recorded speech of speakers with earplugs and for the same speakers with unoccluded ears at the same signal-to-noise ratio, though there were large differences between speakers. Thus there seems to be no audible change in speakers' voices due to hearing protection, apart from in level.

Among other findings of the main experiment was a tendency for a talker to speak up to  $3\frac{1}{2}$  dB louder in a particular noise level if the previous level had been higher, than if the previous level had been lower. Subjects wearing protection

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also tended to speak more loudly if immediately beforehand they had experienced the noise levels unprotected. Apparently, when wearing hearing protection one soon forgets the true noise level against which one is speaking.

### 3. CONCLUSIONS

- 1 The wearing of hearing protection by a listener in noise levels above about 85 dBA does not degrade speech discrimination.
- 2 A person will speak 2-3 dB more quietly when wearing hearing protection in hazardous noise. This degrades communication. The "quality" of the speaker's voice is apparently unaffected.
- 3. An overall degradation in communication results if both listener and speaker wear hearing protection.
- 4. Earmuffs and earplugs affect speech discrimination to a similar degree when worn by listener or talker, although muffs generally provide greater attenuation.
- 5. The spectrum of a speaker's voice rises at the high frequency end with the increasing effort needed in higher noise levels. This does not appear to be influenced by his wearing hearing protectors.
- 6. The level of a speakers voice increases at only half the rate of the background noise whether or not he wears hearing protectors.
- 7. With prolonged wearing of hearing protection a speaker may "forget" the true noise level and speak gradually more quietly.
- 8. In general visual cueing is very important in higher noise levels. An improvement in intelligibility equivalent to a 10 dB reduction in noise level is possible at 95 dBA noise level, whether this is realised in industry depends on listeners, talkers and conditions.

In general hearing protection is detrimental to person-to-person vocal communication. Also if some workers already have some slight noise induced hearing loss, even the slight benefits gained by listeners may be lost (9).

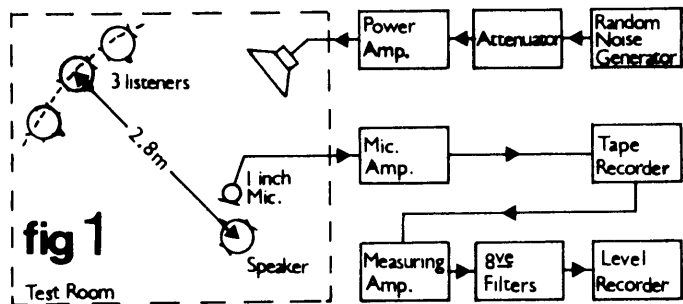
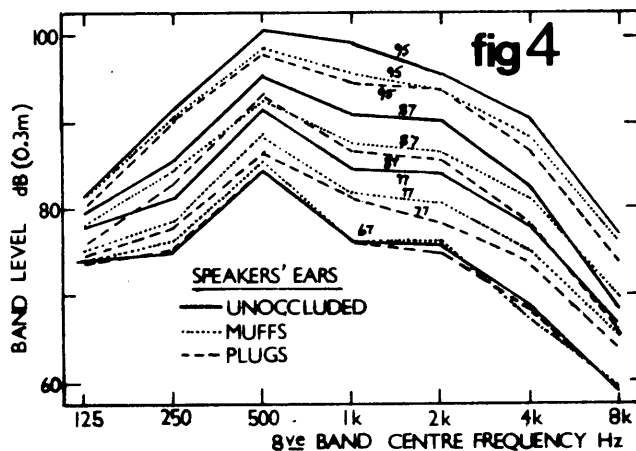
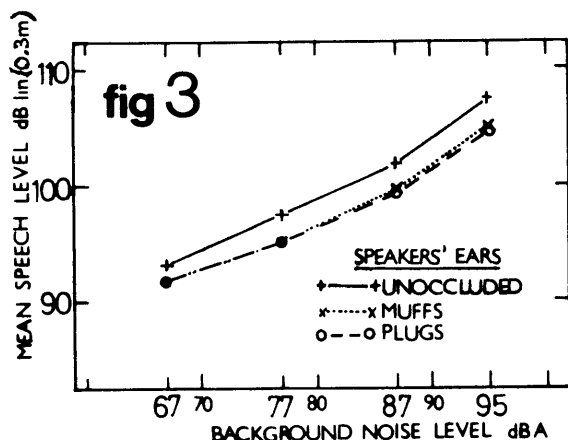


Fig. 1 Experimental set-up.

Fig. 3 Effect of ambient noise level and speakers' hearing protection on mean speech levels.

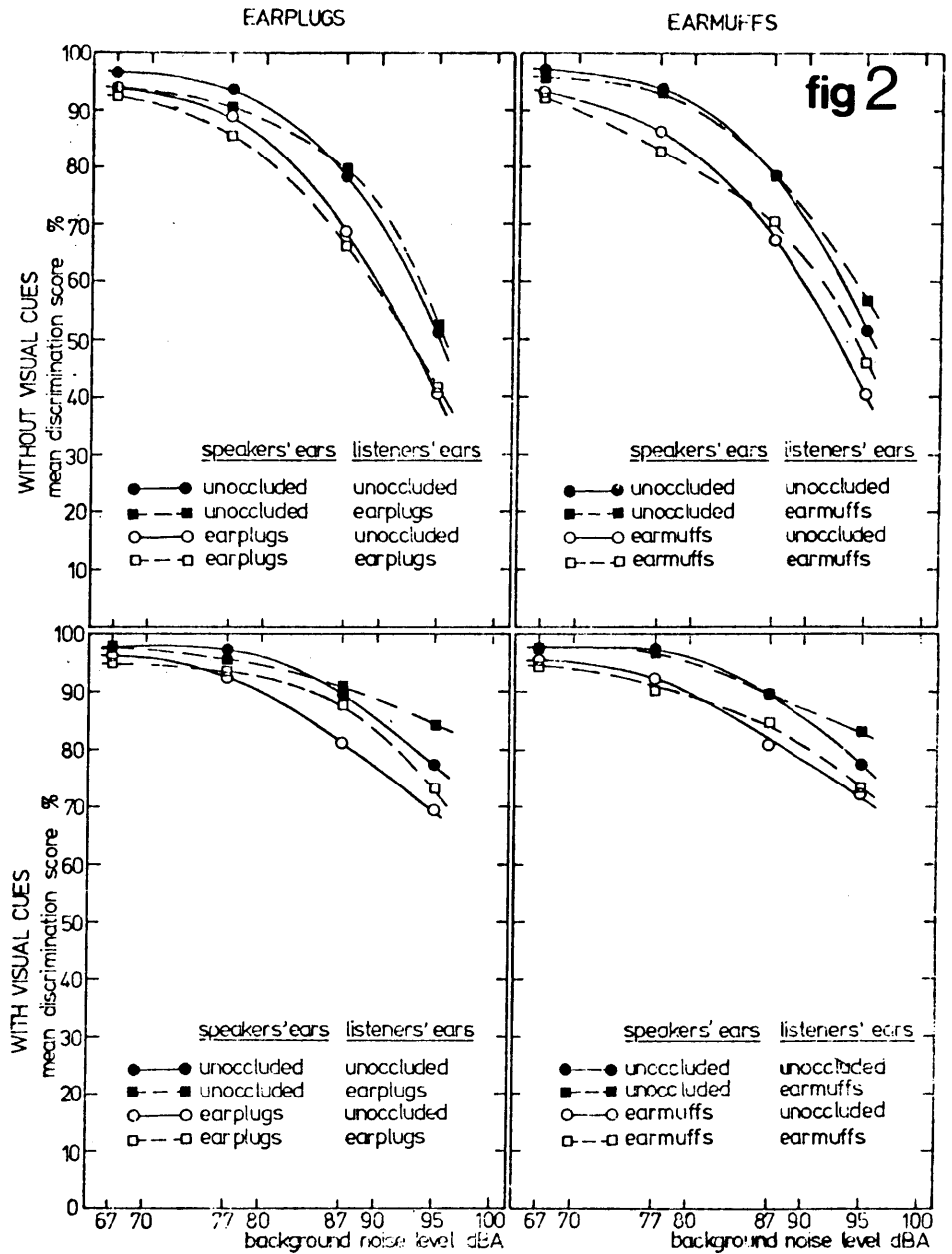
Fig. 4 Octave band analysis of speech (small numbers are b/g noise  $L_A$ .)



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Fig.2 Effect on speech discrimination score, of noise level, listeners' and speakers' hearing protection, and visual cueing.



### 4. REFERENCES

1. Kryter, 1946; J. Acoust. Soc. Am. 18, 413-417.
2. Pollack, 1957; J. Acoust. Soc. Am. 29, 1324-1327.
3. Michael, 1965; Arch. Environ. Health 10, 612-618.
4. Williams et al, 1971; Aerospace Med., 42, 750-752.
5. Howell and Martin, 1975; J. Sound Vib. 41, 181-196.
6. Boothroyd, 1968; Sound 2, 3-10.
7. Lawrence and Yantis 1957. J. Acoust. Soc. Am. 29, 265-274.
8. Lane and Tranel, 1971; J. Speech Hearing Res. 14 677-709.
9. Lindeman ; 1976. Audiology 15, 348-356.