The Cafeteria Study: Effects of visual cues, hearing protection, and real-world noise on speech recognition

Mary Barrett[1], Kerrianne Costantino[1], Sandra Gordon-Salant[1], Douglas Brungart[2], and Julie Cohen[2]

University of Maryland, College Park[1]; Walter Reed National Military Medical Center, Bethesda MD[2]

Introduction

Previous studies examining the impact of interfering noise on speech understanding conducted in controlled laboratory settings have found that speech recognition deteriorates with increasing noise levels, improves with the addition of visual cues compared to auditory-only conditions, and remains the same with and without the use of hearing protection (Grant & Seitz, 2000; Berger, 1980; Rink, 1979). These studies may not account for the acoustic and social factors that potentially impact a person's ability to communicate adequately in real-world settings. The purpose of this study is to investigate how normal-hearing listeners perform in an interactive communication task when situated in a noisy real-world environment that includes varying levels of competing noise, visual cues, and hearing protection.

Methods

Participants:

- Normal Hearing Listeners (n=38): 18-73 yrs (Mean=25.5)
  - Pure-tone thresholds ≤ 25 dB HL, 250 – 4000 Hz (ANSI, 2010)
  - All listeners were native speakers of English

Stimuli:

- 300 monosyllabic (CVC) Modified Rhyme Test words (House et al., 1963)
  - The target word was presented in the carrier phrase "You will mark… please."
  - The listener selected their answer from six choices

Procedures:

- Participants tested in groups of four
- Test location: UMD cafeteria (lunchtime) or local restaurant (dinnertime)
- Participants had a Nexus tablet and wore a head-tracking device (Fig 1)
  - The tablet instructed one participant at random to say the target word
  - The other three participants chose from six choices on their tablets.
- A sound level meter monitored the level of background noise and target speech across each trial
- Measurements: accuracy, reaction time, degree of head movement, and rating of difficulty
- Conditions (n=4)
  1) Baseline (open ear)
  2) Surgical mask
     - Eliminates visual cues without impacting acoustic speech cues
  3) 3M Combat Arms Earplugs (CAE) Open
     - A non-linear earplug; attenuates loud impulses, not continuous sound
  4) 3M Combat Arms Earplugs (CAE) Closed
     - Acts as a standard passive earplug
- Each condition was presented twice, for a total of 8 blocks of 52 trials
  - In 4 of the blocks, each participant was in a different condition
  - In 4 of the blocks, all participants were in the same condition
  - Data were analyzed by listener condition and talker condition

Figure 1: Experiment set-up in cafeteria

Results

Figure 2a: Accuracy in the four listener conditions

Figure 2b: Accuracy in the four talker conditions

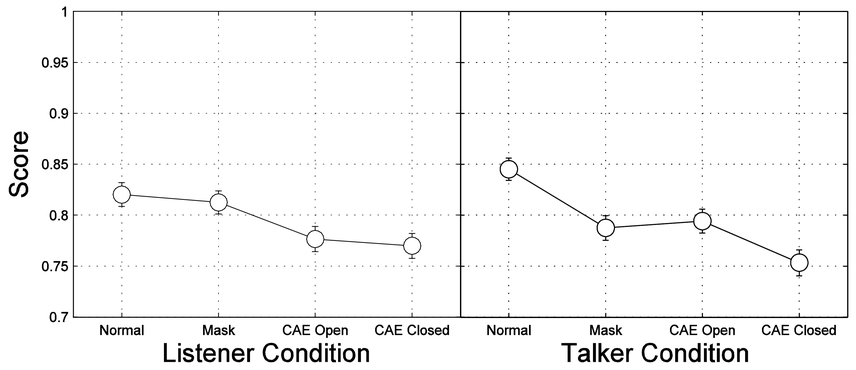

Fig 2: An ANOVA revealed significant main effects of talker condition (p<.001) (Fig 2a) and listener condition (p<.01) (Fig 2b).

Figure 3a: Reaction time in the four listener conditions

Figure 3b: Reaction time in the four talker conditions

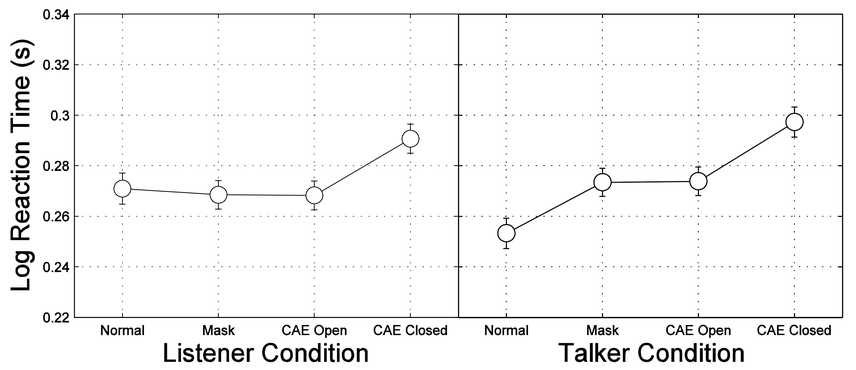

Fig 3: The effect of listener condition was not significant (p>.05) (Fig 3a). However, an ANOVA revealed a significant main effect of talker condition (p<.001) (Fig 3b).

Figure 4a: Talker difficulty rating in the four listener conditions

Figure 4b: Talker difficulty rating in the four talker conditions

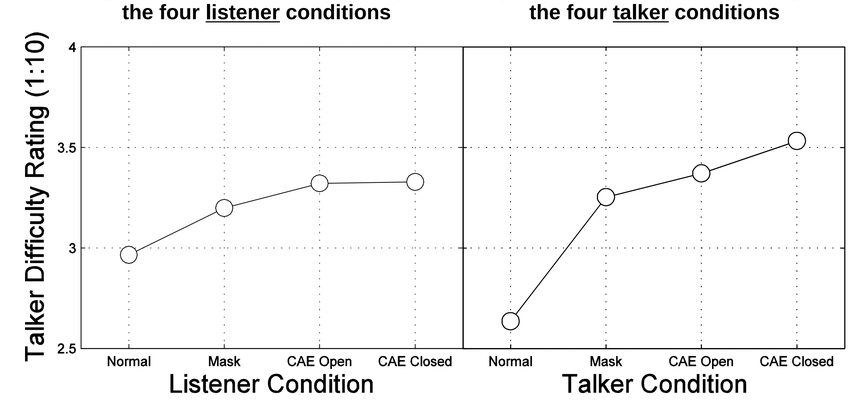

Fig 4: The effect of listener condition was not significant (p>.05) (Fig 4a). However, an ANOVA revealed a significant main effect of talker condition (p<.001) (Fig 4b).

Results (cont'd.)

Figure 5: Accuracy as a function of background noise level

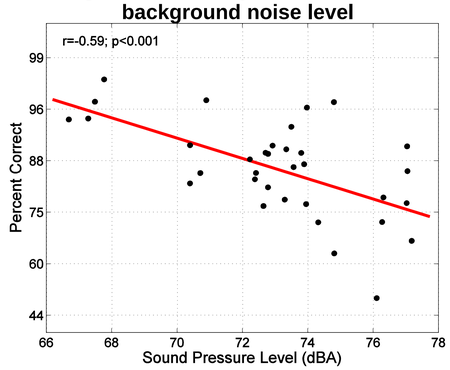

Fig 5: Mean percent correct in normal talker, normal listener condition as a function of noise level in dBA as measured with the SLM.

Figure 6: Max background noise level as a function of block

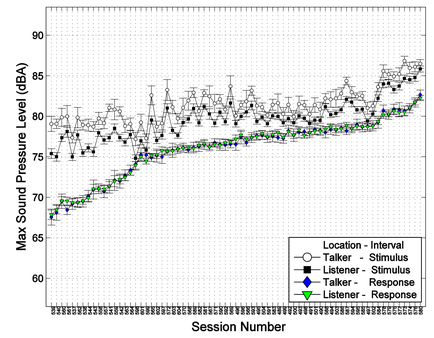

Fig 6: Max SPL by the target and listener tablet microphones in the stimulus and response intervals of each trial.

Discussion

Accuracy

- Recordings of speech and noise levels in real-world conditions indicate talkers do not maintain a constant SNR as noise level increases.
- As the level of background noise increased, the SNR decreased and accuracy declined.
- Accuracy declined when the listener wore earplugs in either the open or closed mode.
- Accuracy declined, relative to the baseline condition, when the talker wore the facial mask or when the talker wore earplugs, with poorer performance when the talker wore closed vs. open earplugs.

Reaction Time

- Listener condition did not have an effect on reaction time.
- Reaction times increased, relative to baseline, in the same talker conditions as noted above when accuracy decreased.

Talker Difficulty Rating

- Listener condition did not have an effect on talker difficulty rating.
- Talkers were rated more difficult, relative to baseline, in the same talker conditions where accuracy decreased and reaction time increased.

Conclusions

Normal hearing listeners' speech recognition performance is adversely affected in real-world situations as background noise increases and visual cues are removed. Additionally, the results show that use of earplugs by normal hearing listeners has a significant effect on the speech recognition abilities of the listener, which is likely due to the attenuation of the target signal by the earplugs. However, one striking aspect of the results is that the percent correct intelligibility, reactions times, and subjective ratings were all degraded more when the *talker* was wearing earplugs than when the *listener* was wearing earplugs. These talker effects are likely due to a combination of the occlusion effect and the Lombard effect (Lindeman, 1976; Tufts & Frank, 2003). It is also interesting that the talker's earplug condition had a strong effect on reaction time and subjective ratings, suggesting that it may be fatiguing to listen to talkers who are wearing earplugs in high levels of noise. The current findings strongly suggest that the effects that earplugs have on talkers' speech in noise, and the effect on listeners, should be included in hearing protection training in hearing conservation programs.

References

Berger, E. H. (1980). The effects of hearing protectors on auditory communications. *Occupational health nursing*, *28*(1), 6.

House, A.S, Williams, C., Hecker, M.H.L, & Kryter, K.D. (1963). Psychoacoustic speech tests: A modified rhyme test. *The Journal of the Acoustical Society of America*, *35*(11), 1899-1899.

Grant, K. W., & Seitz, P. F. (2000). The use of visible speech cues for improving auditory detection of spoken sentences. *The Journal of the Acoustical Society of America*, *108*(3), 1197-1208.

Lindeman, H. E. (1976). Speech intelligibility and the use of hearing protectors. *International Journal of Audiology*, *15*(4), 348-356.

Rink, T. L. (1979). Hearing protection and speech-discrimination in hearing-impaired persons. *Sound and Vibration*, *13*(1), 22-25.

Tufts, J. B., & Frank, T. (2003). Speech production in noise with and without hearing protection. *The Journal of the Acoustical Society of America*, *114*(2), 1069-1080.

Acknowledgments

Funding in part provided by Creare, Inc. The views expressed are those of the authors and do not necessarily reflect the official policy or position of the Departments of the Navy, the Army, the Department of Defense or the U.S. Government.