Modeling Speech Production in Noise to Code Vocal Effort for Use with Communication Headsets

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Communication in Noise

Passive HPD

2-Way Personal Radio

Level Dependent HPD

Passive HPD equipped with radio capabilities

Level dependent HPD with 2-Way communication
Communication in Noise

No intended Receivers!
Speech Production

Speakers adjust their vocal effort:

1. In the presence of noise

2. To express emotion

3. To communicate at distances
Speech Production

Open Ear

In Noise:

- ↑ 1-6 dB ↑ 10 dB of noise (Lane and Tranel, 1971)
- ↑ Fundamental frequency (0.6-2.5 semitones)
- ↑ Spectral center of gravity (Tufts & Frank, 2003; Lu & Cooke, 2008; Garnier & Henrich, 2014)

With Distance:

- ↑ 1.3-6 dB as distance doubles (Traunmüller & Eriksson, 2000; Pelegrín-García et al., 2011; Zaborik & Kelly, 2007)
- ↑ 5 Hz/dB in fundamental frequency (Liénard & Di Benedetto, 1999)
- ↑ 3.5 Hz/dB in first formant
Speech Production
Open Ear

Distance Model:

\[ L_w = 59.54 + 2.96 \times \log_2(d/1.5) \]

(Pelegrín-García et al., 2011)
Speech Production

Open Ear

Distance Model in the presence of Noise:

\[ L_w = 59.54 + 2.96 \times \log_2(d/1.5) + n \times [10 + 0.3 \times (N - 60)] \]
Speech Production

Occluded Ear

In quiet:
• No significant change in voice level for occluded ear

(Tufts & Frank, 2003; Navarro, 1996)

In Noise:
• No significant increase in level at 60 dB noise
• ↓ 4-11 dB from open ear condition
• ↑ 1.25 dB for every ↑ 10 dB of noise

(Tufts & Frank, 2003)

With Distance:

?
Speech Production

Occluded Ear

Distance Model in the presence of Noise for the occluded ear:

\[ L_w = 59.54 + 2.96 \times \log_2 (d/1.5) + n \times 0.125 \times (N - 60) \]
Speech Production

Occluded Ear

Distance Model in the presence of Noise for the occluded ear:

\[ L_w = 59.54 + 2.96 \times \log_2 (d/1.5) + n \times 0.125 \times (N - 60) \]

Assumptions:

1. In noise wearing HPDs does not greatly affect the speech production process as a function of the communication distance from the open-ear condition.

1. In quiet wearing HPDs would not affect the speech production process as a function of distance.
Proposed Experimental Protocol

1. It is intra-aural
   - (foam, flange, putty, etc.)
2. IEM, OEM and Miniature loudspeaker
3. RAVE
Proposed Experimental Protocol

• 5 different communication distances:
  o 0.3m, 5m, 10m, 15m, and 20m
• Instruct the listener a color and a digit (repeated 20 times)
  o 20 different times.
  o 4 different colors (Red, Green, Blue, Yellow)
  o 10 different digits (0-9).

5 conditions:
• in quiet
• in noise ranging from 60 dB to 90 dB
  at increments of 10 dB.
Conclusions

• Enhancing communication in noise while using HPDs with personal radios

• Relationship between vocal effort, communication distance and background noise level for occluded ear
Radio Acoustical Virtual Environment

- Low noise level: 20
- Moderate noise level
- High noise level

Extreme noise level

Transmitted

Not transmitted