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

Rachel E. Bouserhal
Tiago H. Falk
Jérémie Voix
Outline

• Background
• Research Questions
• What we know
• What we should know
• How we’re going to figure it out
• What we’ve done so far
• Conclusions
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 !
Radio Acoustical Virtual Environment

- Low noise level
- 20
- 15
- 10
- 5
- Moderate noise level
- Extreme noise level
- High noise level

transmitted
not transmitted
Research Questions

• How can we enhance communication for persons wearing HPDs in noisy environments?

• What is the relationship between vocal effort, communication distance and background noise level for occluded ear?
Auditory Research Platform

a. earpiece
wireless link

b. internal receivers
In-Ear Microphone (IEM)
Outer-Ear Microphone (OEM)

c. wireless link
Outer-Ear Microphone (OEM)
electronics and DSP
internal receivers
In-Ear Microphone (IEM)
Enhancement of in-ear microphone speech
Next Step...

Vocal Effort Coding
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; Zahirik & Kelly, 2007)
- ↑ 5 Hz/dB in fundamental frequency  (Liénard & Di Benedetto, 1999)
- ↑ 3.5 Hz/dB in first formant  (Traunmüller & Eriksson, 2000; Pelegrín-García et al., 2011; Zahirik & Kelly, 2007)
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  
  (Tufts & Frank, 2003)
• ↑ 1.25 dB for every ↑ 10 dB of noise

With Distance:

?
Speech Production

Occluded Ear

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

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

1. It is intra-aural
   - (foam, flange, custom molded 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.
So far...

A little show and tell!
Enhancement of In-ear Microphone Speech
Conclusions

• Relationship between vocal effort, communication distance and background noise level for occluded ear

• Enhancing communication in noise while using HPDs with personal radios
Radio Acoustical Virtual Environment

- Low noise level
- Moderate noise level
- Extreme noise level
- High noise level

- Transmitted
- Not transmitted
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.