Assessing Sound Source Localization in Listeners with Bilateral Cochlear Implants

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Introduction

- Listeners with bilateral cochlear implants (BCIs) exhibit different sound source localization than those with normal hearing (NH; Fig. 1).
- Methods of analysis developed for NH may not be optimal for BCI.
- Implications for everyday listening (e.g., poorer localization at far angles, bias toward one side, greater variability in perceived location)

- Characterizing changes with localization that depend upon patient-dependent factors could improve our ability to counsel patients.
  - Age at onset of deafness [1-2]
  - Delay in implantation between ears [3-4]

Results: Shape of Localization Function

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

X

Y

Z

Fig. 1: Example data from individual listeners with NH (A) or BICIs (B). The x-axis indicates the location where the sound was presented. The y-axis indicates the perceived location from the subject. Error bars represent ± 1 standard deviation.

- Variability across subjects, with some consistent trends (Fig. 3):
  - Greater variability and errors at lateral target angles.
  - Tendency for some subjects to respond in the center for all targets.
  - Larger standard deviations compared to NH (c.f., Fig. 1A)

Significance: Each statistical approach indexes different aspects of performance (i.e., accuracy, confusion, and shape of function).

Dataset & Methods

- Participants: 48 patients with BICIs
- Task: Perceived location was indicated on a touch-screen
  - Presented in free-field
  - 19 speakers from ±90 degrees in 10-degree steps
  - 15 repetitions per speaker
- Stimuli: Trains of 4 pink noise bursts
  - 170 ms each, with 50 ms inter-stimulus interval
  - 50 dB SPL(A) ± 4 dB level rove and ± 10 dB spectrum rove

Summary

- Prior approaches have been unable to illuminate characteristic differences in localization patterns associated with patient-dependent factors with BICIs.
- Root-mean-square error showed poorer performance when patients had a longer delay in implantation between each ear, which was compounded when patients acquired deafness ≤ 5 years (Table 1).
- Localization sensitivity index was highly correlated with RMS error.
- Logistic regression showed shape of localization varies across patients, but may not be related to the patient-specific factors investigated in this study (Fig. 6).
- Novel approach: Machine classification showed high variability in localization responses at lateral locations for patients that acquired deafness ≤ 5 years, and heterogeneous outcomes for patients that acquired deafness > 5 years (Fig. 8).
- Localization patterns influenced by patient-dependent factors
- Patient care might be optimized by considering these characteristic differences in localization performance.

Statistical Approaches

1. Root-Mean-Square (RMS) Error
2. Localization Sensitivity Index (LSI)
3. Logistic Regression
4. Machine Classification

- Included target angle and squared target angle in regression to predict log(RMS error)
  - Squared term accounts for errors at target angles
  - Revealed significant effect of inter-implantation delay and interaction with age of onset of deafness (Table 1)

Results: Errors and Confusions

- Most patients did not exhibit ideal localization performance (Fig. 8).
- Patients that acquired deafness ≤5 years had accurate means but were more variable at lateral target angles.
- Patients that acquired deafness > 5 years had heterogeneous localization outcomes.
- More individuals with smaller variability (i.e., ideal standard deviations)

References


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