Perceptual Identification of Environmental Sounds Under a Cochlear Implant Simulation

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Introduction

Environmental sounds, though pervasive in everyday life, are understudied in comparison to other auditory stimuli, such as speech and music. A variety of factors can influence one’s ability to identify environmental sounds including familiarity, duration, and complexity (Marcell et al., 2000). Gygi and colleagues (2004) found that some frequency regions may be more informative than others for the recognition of environmental sounds, and overlap significantly with regions also important for speech perception. However, the complete removal of spectral information still allowed participants to identify 35 out of 70 environmental sounds with at least 50% accuracy, indicating the importance of temporal cues. This finding has strong implications for cochlear implant (CI) users, since cochlear implants produce spectrally degraded information, but maintain the temporal components of sounds.

While CI users are frequently tested on their ability to comprehend speech, little attention is given to their ability to identify the environmental sounds that they encounter on a daily basis. Previous research has suggested that training with environmental sounds could enhance both the perception of environmental sounds and speech for CI users (Loebach & Pisoni, 2008). Our research is part of a larger study investigating the long-term perceptual learning of CI simulations in normal hearing individuals in order to develop a proposed training program for new adult CI users. The focus of our analyses was on the predicted benefits of training on environmental sound perception and on the components of environmental sounds that can lead to better or worse identification.

Method

- 120 normal hearing undergraduates at St. Olaf College (sex: 73f, 43m; mean age: 20.6 years)
- Participants were assigned into three groups:
  1. One-day Control Group (n=37)
  2. Two-day Control Group (n=12)
  3. One-day Control Group (n=37)
- Participants were trained over four days on a variety of speech and nonspeech materials (talker voice identification, meaningful sentences, anomalous sentences, words, environmental sounds)

Participants tested on Day 5 (n=37)
- Participants completed the Day 5 test

Results

Main Effect of Training

- Extended training significantly improved environmental sound identification
- F(2, 78) = 15.509, p < 0.001
- Exp > Control, p = 0.230
- Exp > Two-day, p = 0.191

Cluster Analysis

- Two-step cluster identified two groups of sounds for each condition that were identified with high accuracy (high ID) or low accuracy (low ID)
- F(1, 22) = 646.908, p < 0.001
- 39 out of 44 sounds remained in same cluster across all conditions
- 5 sounds changed cluster identity
- An opening & pull switch: Moved to high ID cluster for experimental group
- Pig: Moved to high ID cluster for two-day and experimental groups
- Flute & brushing teeth: Did not follow expected pattern

Extended training significantly improved identification of sounds within the low ID cluster (Figure 1)
- F(1, 22) = 6.570, p = 0.02
- Exp > Control, p = 0.007
- Exp > Two-day, p = 0.006

Extended training did not significantly improve identification of sounds within the high ID cluster (Figure 2)

Qualitative Analysis of Environmental Sound Characteristics

- Across conditions, nearly all environmental sounds in high ID cluster were not spectral
- Exception: Flute (spectral) was in high ID cluster in the two-day control (possibly due to a small n)
- No transient sounds were in high ID cluster for control or two-day conditions; two transient sounds were in high ID cluster for experimental (pull switch and opening)
- Most sounds in a series (temporal) were in high ID cluster across conditions
- Series sounds in low cluster: woodpecker (often confused with helicopter), turning page (not normally in a series), brushing teeth (in two-day only)
- Most vocalizations were in low ID cluster across conditions
- Vocalizations in high ID cluster: frog (high familiarity), pig (only for two-day and experimental, not spectral)

Discussion

- The five-day training protocol was successful in improving environmental sound perception replicating the findings of Loebach & Pisoni (2008) and Sharf (2008)
- Since the two-day control improvement was not significant, the observed effect was not due to mere exposure
- Generally, sounds clustered into two different groups: high ID and low ID
- Since most sounds remained in the same cluster across conditions, the improvement must be occurring within each cluster
- Training only improved identification in the low ID cluster
- High ID cluster had higher starting levels leaving less room for improvement
- Preliminary qualitative analyses revealed characteristics important to sound identification
- High ID cluster: non-spectral sounds, series
- Low ID cluster: transient sounds, vocalizations
- Participants were trained on the basis of the vocoder simulated which mimics the trends seen in CI users (Shannon, 2002)
- Spectral cues are degraded in the cochlear implant speech processor and vocoder alike, and thus are more difficult to utilize in identification
- Temporal cues are preserved
- Series are easier to identify due to characteristic rhythms for that sound (e.g. horse galloping) and multiple repetitions providing more context
- The sheer variability of vocalizations makes them more difficult to identify (e.g. a dog’s bark could be a single transient sound, a series of barks, or a non-transient howl)
- Familiarity increased likelihood of identification due to potentially greater prior exposure to the sounds

- The best fit linear regression model for environmental sound identification depended on whether the sound was spectrally driven or not
- Likely to be identified: not spectral, more familiar, in a series
- Not likely to be identified: spectral, less familiar, transient, vocalizations
- Quantitative analysis confirmed what was found qualitatively and allowed for comparison of the importance of combinations of factors, revealing that familiarity also played a role when participants did not undergo full experimental training
- Due to smaller sample size of two-day control, no significant model was observed for examined characteristics

- Overall, results support the necessity of training for CI users, as evidenced by improved environmental sound identification
- Specifically, training on more poorly identified sounds may be most beneficial
- Training on environmental sounds in conjunction with a comprehensive speech training paradigm will hopefully lead to improved auditory perception in CI users
- In the future, this study will be replicated with CI users in order to assess the validity and applicability of these results with the hope of assisting CI users to make the most of their devices.

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