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Performance variability on perceptual discrimination tasks in profoundly deaf adults with cochlear implants

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ABSTRACT

Objectives: The purpose of this study was to evaluate performance on two challenging listening tasks, talker and regional accent discrimination, and to assess variables that could have affected the outcomes.
Study design: A prospective study using 35 adults with one cochlear implant (CI) or a CI and a contralateral hearing aid (bimodal hearing) was conducted. Adults completed talker and regional accent discrimination tasks.
Methods: Two-alternative forced-choice tasks were used to assess talker and accent discrimination in a group of adults who ranged in age from 30 years old to 81 years old.
Results: A large amount of performance variability was observed across listeners for both discrimination tasks. Three listeners successfully discriminated between talkers for both listening tasks, 14 participants successfully completed one discrimination task and 18 participants were not able to discriminate between talkers for either listening task. Some adults who used bimodal hearing benefitted from the addition of acoustic cues provided through a HA but for others the HA did not help with discrimination abilities. Acoustic speech feature analysis of the test signals indicated that both the talker speaking rate and the fundamental frequency (F0) helped with talker discrimination. For accent discrimination, findings suggested that access to more salient spectral cues was important for better discrimination performance.
Conclusions: The ability to perform challenging discrimination tasks successfully likely involves a number of complex interactions between auditory and non-auditory pre- and post-implant factors. To understand why some adults with CIs perform similarly to adults with normal hearing and others experience difficulty discriminating between talkers, further research will be required with larger populations of adults who use unilateral CIs, bilateral CIs and bimodal hearing.

1. Introduction

For adults with severe-to-profound deafness, cochlear implants (CIs) have greatly improved their communication abilities (Firszt,

Abbreviations: CI, cochlear implant; HA, hearing aid; PTA, pre-implant pure-tone average; PTS_CI, post-implant pure-tone average; SPEAK, spectral peak; ACE, advanced combination encoder; CIS, continuous interleaved sampling; MPS, multiple pulsatile sampler; ANOVA, analysis of variance

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Holden, Reeder, Cowdrey, & King, 2012; Gifford, Dorman, Shallop, & Sydlowski, 2010; Zeng, 2004). Some adults who were once incapable of participating in conversations because of their deafness, now achieve up to 100% word and sentence understanding in quiet environments (Gifford et al., 2010; Wilson & Dorman, 2008). However, a large amount of performance variability exists and much more research is needed to more fully appreciate the underlying reasons for poor performance with a CI (Bierer, Spindler, Bierer, & Wright, 2016; Holden et al., 2016; Moberly, Bates, Harris, & Pisoni, 2016a). Some adults with CIs perform similarly to adults with normal hearing but others struggle to understand monosyllabic words presented in quiet environments (Bierer et al., 2016; Moberly, Lowenstein, & Nittrouer, 2016b). The purpose of this study was to examine performance variability on two challenging listening tasks, talker and accent discrimination, in adults who use one CI or a CI and a contralateral hearing aid (bimodal hearing).

Evidence has suggested that listeners with CIs struggle to perceive spoken language because of the poor spectral resolution that results from the CI speech processing algorithms. That is, the limited number of spectral channels (Nie, Barco, & Zeng, 2006; Xu & Pfingst, 2008), the interactions between the electrodes within the device (Stickney et al., 2006), and the distorted tonotopic map that results from placement of the electrode array within the cochlea (Li & Fu, 2010) all contribute to poorer spectral resolution. Additionally, other data suggest that as spectral information of speech processed through a CI declines, listeners rely more heavily on temporal cues for speech perception (Nie et al., 2006; Schvartz, Chatterjee, & Gordon-Salant, 2008; Xu, Thompson, & Pfingst, 2005).

Others have demonstrated that specific pre-operative auditory and non-auditory factors explain postoperative performance. Specifically, those with longer durations of deafness prior to implantation, age of implantation, and duration of CI use has been shown to explain outcome performance (Blamey et al., 1996; Blamey et al., 2013; Lazard et al., 2012). Recently, however, the duration of deafness prior to implantation has been shown to be less important than it has been in the past most likely due to the relaxed candidacy criteria for those seeking implantation (Blamey et al., 2013). The degree of pre-implant residual hearing has also been shown to be beneficial for post-implant performance. Individuals with a greater degree of residual hearing prior to implantation perform better on a wide range of speech perception tasks compared to individuals with less residual hearing (Francis, Yeagle, Bowditch, & Niparko, 2005; Gantz, Woodworth, Knutson, Abbas, & Tyler, 1993; Gomaa, Rubinstein, Lowder, Tyler, & Gantz, 2003). Researchers also have observed that more low frequency residual hearing prior to implantation is important for post-implantation speech perception (Marx et al., 2015; Mulhern & Cullington, 2014).

Factors affecting performance on listening tasks also include the acoustic properties of the presented stimuli. The fundamental frequency (F0) and the speaking rate of the talker can influence the outcomes. Fuller et al. (2014) demonstrated that adults who use cochlear implants relied on talker F0 cues for gender categorization rather than using both F0 and vocal track length (VTL) cues. Listeners with normal hearing use both F0 and VTL for gender categorization. Fu, Chincilla, Nogaki, and Galvin (2005) assessed voice-gender identification in a group of CI and normal hearing listeners using two sets of male and female talker stimuli. One set of talkers had a mean difference in F0 of 100 Hz across talkers and the other group of talkers had a 10 Hz mean difference. It was found that both the normal hearing listeners and CI users had better voice-gender identification when listening to the group of talkers with the 100 Hz separation in F0 compared to the group of talkers with the 10 Hz separation in F0. Additionally, findings have suggested that the speaking rate of the talker will have a dramatic impact on cochlear implant listeners' spoken word understanding. Ji, Galvin, Xu, and Fu (2013) found that when listening to synthetic speech presented at twice the normal speaking rate, CI listeners' understanding of IEEE sentences was much poorer than their understanding of the speech presented at a normal speaking rate and at half the normal speaking rate.

For some, the use of a contralateral hearing aid and the access it provides to low-frequency acoustic cues improves word recognition in quiet and in noise, the identification of Mandarin tones and timbre, and music perception (Kong, Cruz, Jones, & Zeng, 2004; Kong, Mullangi, & Marozeau, 2012; Kong, Stickney, & Zeng, 2005; Li, Zhang, Galvin, & Fu, 2014; Yoon, Shin, Gho, & Fu, 2015). Presumably, access to low frequency acoustic cues provided through a hearing aid most likely was helpful for these listening tasks. However, within studies, a large amount of variability is observed with some receiving significant benefit from bimodal hearing and others receiving very little, if any, benefit (Ching, van Wanrooy, & Dillon, 2007; Choi et al., 2016; Incerti, Ching, & Cowan, 2013; Mulhern & Cullington, 2014). Evidence has suggested that those with more residual low-frequency hearing, or pure tone averages for 250 Hz, 500 Hz, and 1000 Hz better than 60 or 70 dB, obtained more bimodal benefit than those with poorer low-frequency residual hearing (Blamey et al., 2015; Choi et al., 2016; Reiss, Eggleston, Walker, & Oh, 2016).

In the present study, we tested a group of listeners who used unilateral cochlear implants and a group who used bimodal hearing on two challenging listening tasks, talker and regional accent discrimination, and assessed variables affecting outcomes. Participants were asked to discriminate between male and female talkers who had general American accents, and additionally, to discriminate between same-gender talker-pairs of sentences with northern American and southern American accents. Understanding challenges that adults with cochlear implants experience may help to improve post-implantation clinical management, perhaps through participating in an individually designed post-implantation rehabilitation programs that focus on the development of specific perception skills, and/or through the use of a contralateral hearing aid.

2. Material and methods

2.1. Participants

Data from 35 study participants who participated in an earlier vowel identification study were used for this study (Hay-McCutcheon, Peterson, Rosado, & Pisoni, 2014). All 35 post-lingually deaf adults received a cochlear implant at the Department of Otolaryngology—Head and Neck Surgery at the Indiana University School of Medicine. The project was carried out according to basic ethical standards for the protection of human research subjects and was approved by the Institutional Review Boards at Indiana