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Perceptual learning and nonword repetition using a cochlear implant simulation

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Abstract

This study examined the effects of perceptual learning on nonword repetition performance of normal-hearing listeners who were exposed to severely degraded auditory conditions that were designed to simulate the auditory input of a cochlear implant. Twenty normal-hearing adult listeners completed a nonword repetition task using an eight-band, frequency-shifted cochlear implant simulation strategy both before and after training on open- and closed-set word recognition tasks. Feedback was provided during training. The nonword responses obtained from each participant were digitally recorded and played back to normal-hearing listeners. These listeners rated the nonword repetition accuracy in comparison to the original unprocessed target stimuli using a seven-point scale. The mean nonword accuracy ratings were significantly higher for the non words repeated after training than for non words repeated prior to training. These results suggest that the word recognition training tasks encouraged auditory perceptual learning that generalized to novel, nonword auditory stimuli. The present findings also suggest that adaptation and learning from the degraded auditory stimuli produced by a cochlear implant simulation can be achieved even in a difficult perceptual–motor task such as nonword repetition which involves both speech perception and production of an auditory stimulus that lacks any lexical or semantic representation.

Keywords

Cochlear implant; Nonword repetition; Perceptual learning; Speech perception

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1. Introduction

The ability to recognize speech from the degraded auditory input provided by a cochlear implant has been shown to be related to cochlear implant users' digit spans [1] and nonword repetition skills [2], Simulation studies of cochlear implants have been useful in estimating speech perception accuracy and performance by normal-hearing listeners in a variety of word recognition and memory tasks under degraded auditory conditions [3]. Cochlear implant simulation studies have also been used to demonstrate rapid perceptual learning and

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auditory adaptation after training with a variety of auditory stimuli such as consonants, vowels, words, and sentences [4].

In this study, nonword repetition performance was assessed before and after auditory training in normal-hearing adults who listened to a cochlear implant simulation with a frequency shift [5]. Nonword repetition is a perceptual–motor task that requires listeners to repeat novel auditory patterns that sound like possible English words [6].

An advantage to using the nonword repetition task over sentence and word identification is that there are no contextual or lexical influences associated with nonwords. A nonword repetition task may also be preferable to vowel identification because it is more similar to everyday listening and word learning conditions. This study was designed to investigate whether training with degraded auditory stimuli can promote perceptual learning to novel, nonword auditory stimuli that lack semantic and lexical representations.

2. Methods and materials

Twenty normal-hearing adults completed training and nonword repetition tasks while listening to an acoustic simulation of a cochlear implant [5], Three of the participants were male, and 17 were female. Prior to training, participants repeated 20 phonologically permissible nonwords, in their processed form. A 30-min training period using closed- and open-set word recognition tasks was administered to all participants. In the closed-set word recognition tasks, sets of four and six pictures representing the correct training word and foils were presented to participants. Open-set training used easy and hard words taken from the Lexical Neighborhood Test (LNT). As feedback, the unprocessed word was played back to listeners after they responded. After training, participants repeated 20 new nonwords. All nonword responses were recorded onto digital audio tape. A sample of nonwords used in the tasks is shown in Table 1.

The recorded nonword responses were played back to a separate group of 80 normal-hearing listeners. The utterances of each participant were given accuracy ratings by four different listeners. Ratings were based on how similar each nonword repetition response sounded compared to the unprocessed target nonword. The target nonword was first played to the listeners. After a one second interval, the corresponding nonword response from one participant was played. A seven-point scale (1=nonword bears no resemblance to the target, 7=nonword sounds perfectly like the target) was used to make the ratings. The ratings of nonwords repeated prior to training were compared to those repeated after the training period.

3. Results

3.1. Speech perception performance in training tasks

Accuracy on the closed-set word recognition task was significantly better than accuracy on the open-set word recognition tasks ($t(18)=40.56$, $p=0.000$). The four alternative closed-set task was easier for participants to complete than the six alternative closed-set task ($t(18)=6.33$, $p=0.000$). In addition, easy words on the LNT were identified more accurately than hard words ($F(1,54)=24.35$, $p=0.000$). Fig. 1 shows the percentage of words correctly identified on the closed- and open-set word recognition tasks.

3.2. Nonword repetition ratings

The mean accuracy ratings of nonwords repeated both before and after training were near the lower end of the seven-point ratings scale. However, the mean accuracy ratings assigned to nonwords repeated after training were significantly higher than the ratings assigned to

nonwords repeated prior to the training period ($t(18)=4.76$, $p=0.000$). Fig. 2 shows the mean accuracy ratings of the nonwords repeated before and after training.

4. Discussion

Repeating nonwords under conditions of cochlear implant simulated speech was a difficult task for these normal-hearing listeners. However, an increase in nonword accuracy ratings after training indicates that perceptual learning can occur even for stimuli that are completely novel and have no lexical or semantic meaning or representation in long-term memory. This type of perceptual learning may rely on phonological processing skills which involve decomposition of the nonword input pattern into a sequence of segments and the reassembly of these patterns in speech production without lexical support.

Acknowledgments

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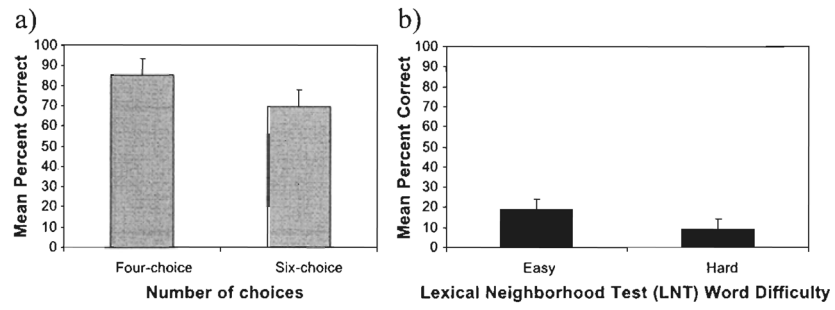
Fig. 1.
Mean scores obtained in (a) closed-set and (b) open-set word recognition tasks. Error bars represent the standard error of the mean.
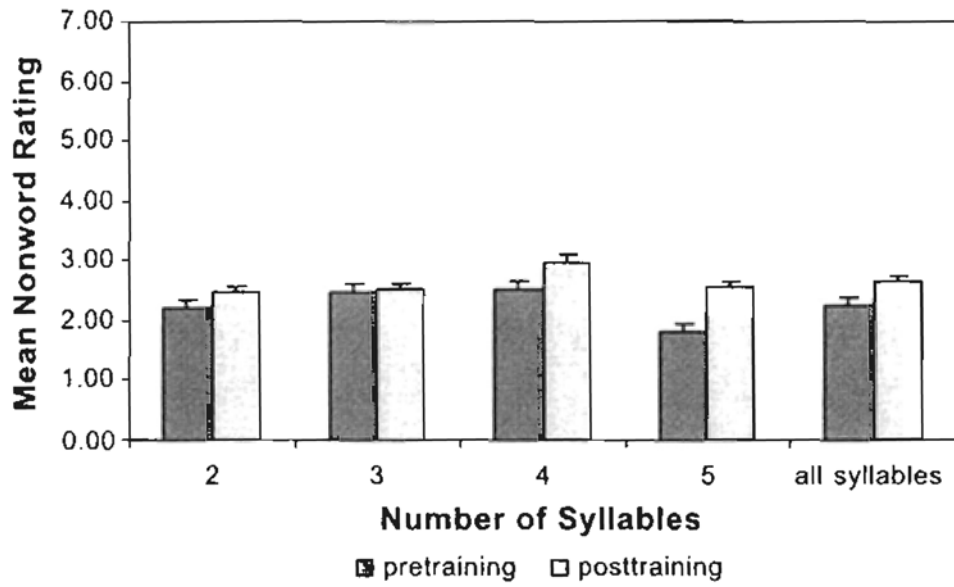
Fig. 2.
Mean nonword ratings assigned to nonwords repeated before and after a period of word recognition training. Error bars represent the standard error of the mean.

Table 1

Sample of nonwords used in the current study

Syllables	Nonword Orthography	Nonword Transcription
	ballop	ˈbæ.ləp
	prindle	ˈprɪn.dl̩
2	rubid	ˈruˌbɪd
	sladding	ˈslæ.dɪŋ
	tafflist	ˈtæ.flɪst
	bannifer	ˈbæ.nəˌfɚ
	berrizen	ˈbɛ.rəˌzɪn
3	doppolate	ˈdɑ.pəˌleɪt
	glistering	ˈglɪ.stɚ.ɪŋ
	skiticult	ˈskɪ.rəˌkʌlt
	comisitate	kəˈmi.səˌteɪt
	contramponist	kənˈtɹæm.pəˌnɪst

Syllables	Nonword Orthography	Nonword Transcription
4	emplifervent	ɛmˈplɪ.fɚˌvɛnt
	fennerizer	ˈfɛ.nɚˌaɪ.zɚ
	penneriful	pəˈnɛ.ɹəˌfʌl
	altupatory	ælˈtu.pəˌtɔ.ri
	detratapillic	diˈtræ.ɹəˌpɪ.lɪk
5	pristeractional	ˈprɪ.stɚˌæk.ʃə.nl̩
	versatrationist	ˈvɚ.səˌtɹeɪ.ʃəˌnɪst
	voltularity	ˈvɑl.tʃʊˌlɛ.ɹəˌti