

**RESEARCH ON SPOKEN LANGUAGE PROCESSING**

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**Some New Directions in Evaluating the Speech Perception Abilities of  
Cochlear Implant Patients: A Preliminary Report<sup>1</sup>**

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## Abstract

These studies investigated the influence of two nonphonetic factors, stimulus variability and lexical difficulty, on the speech perception abilities of cochlear implant (CI) patients and normal-hearing listeners. The effects of stimulus variability were evaluated by comparing identification performance for isolated words presented in single-talker versus multiple-talker contexts. The influence of lexical difficulty was examined by comparing recognition scores for "easy" versus "hard" words--as defined by the Neighborhood Activation Model (Luce, et al., 1990). Additionally, the investigations were designed to establish whether stimulus variability and lexical difficulty would have differential effects on identification performance in open- and closed-set response formats. The results demonstrated that open-set identification scores for both normal-hearing listeners and cochlear implant patients were significantly reduced when words were produced in multiple-, compared to single-talker contexts. Significant effects of lexical difficulty were also observed in both subject populations; scores for lexically "hard" items were significantly worse than for lexically "easy" items. In closed-set formats, however, the effects of both stimulus variability and lexical difficulty were substantially attenuated. These results suggest that if the goal of assessment protocols for CI patients is to measure speech perception abilities under conditions simulating natural listening environments, then instruments employing open-set formats and multiple-talker contexts will provide more valid measures of such capabilities than traditional clinical evaluations.

# Some New Directions in Evaluating the Speech Perception Abilities of Cochlear Implant Patients: A Preliminary Report

## INTRODUCTION

Although recent investigations of spoken-word recognition have established several nonphonetic factors that can influence spoken-language processing, these findings have generally not been integrated into traditional clinical assessment instruments. The present studies investigated the influence of two such factors, stimulus variability and lexical difficulty, on spoken-word recognition by cochlear-implant and normal-hearing subjects. The effects of stimulus variability were assessed by comparing identification performance for isolated words presented in single-talker versus multiple-talker contexts. The influence of lexical difficulty was examined by comparing spoken-word recognition scores for lexically "easy" versus lexically "hard" stimulus items, as defined by the Neighborhood Activation Model (Luce, 1986). In addition, the experiments were designed to establish whether stimulus variability and lexical difficulty would have differential effects on identification performance in open- and closed-set response formats.

## PURPOSE

The present investigations were designed to examine the importance of stimulus variability, lexical difficulty, and response format for assessing the speech perception abilities of CI patients. Specifically, the studies addressed the following questions:

- 1) Do CI patients exhibit poorer identification performance for word lists produced by multiple, as opposed to single, talkers?
- 2) Do CI patients show differences in identification performance for lexically easy vs. hard words?
- 3) Are the effects of stimulus variability and lexical difficulty limited to open-set response formats?

## METHOD

### Subjects

Table 1 lists subject information for the normal-hearing and cochlear implant subjects tested in these studies.

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Insert Table I here  
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### Stimuli

- 100 highly familiar words from Modified Rhyme Test (MRT)
- **EASY WORDS:** High-frequency words from low-density, low-frequency lexical neighborhoods.
- **HARD WORDS:** Low-frequency words from high-density, high-frequency lexical neighborhoods.

**Table 1**

Subject information for normal-hearing and cochlear implant subjects.

### **Normal-Hearing Subjects**

Condition	N	Mean Age	PTA(L)	PTA(R)
Open-set(Q)	12	19.4	normal	normal
Open-set (-5 S/N)	12	23.3	normal	normal
Closed-set(Q)	12	18.1	normal	normal
Closed-set(-5 S/N)	12	24.2	normal	normal

### **Cochlear Implant Subjects**

Subject	Age	Implant Device	Duration	Etiology
AC	37	Nucleus 22	3 years	Meningitis
LN	39	Nucleus 22	1.5 years	Meniere's
RR		Nucleus 22	1 year	
JB	33	Nucleus 22	3.5 years	Unknown
ES	61	Clarion	9 months	Meniere's

## Identification Tests

### Open-set condition

#### Response procedures

- Normal-hearing subjects were required to type the word they thought was presented on a keyboard. Cochlear implant patients were asked to write their responses on an answer sheet.

#### Presentation levels

- Normal-hearing listeners: Stimuli presented binaurally at 70 dB SPL
- Cochlear implant patients: Stimuli presented free field at approximately 70 dB SPL

#### Variability conditions

- Single talker: All words produced by single male voice
- Multiple talker: Voice of talker chosen randomly from 10 talkers (5 male and 5 female) on each trial

### Closed-set condition

- Both Normal hearing and CI subjects: Circle one of six phonemically similar response alternatives to words presented in both single- and multiple-talker contexts.

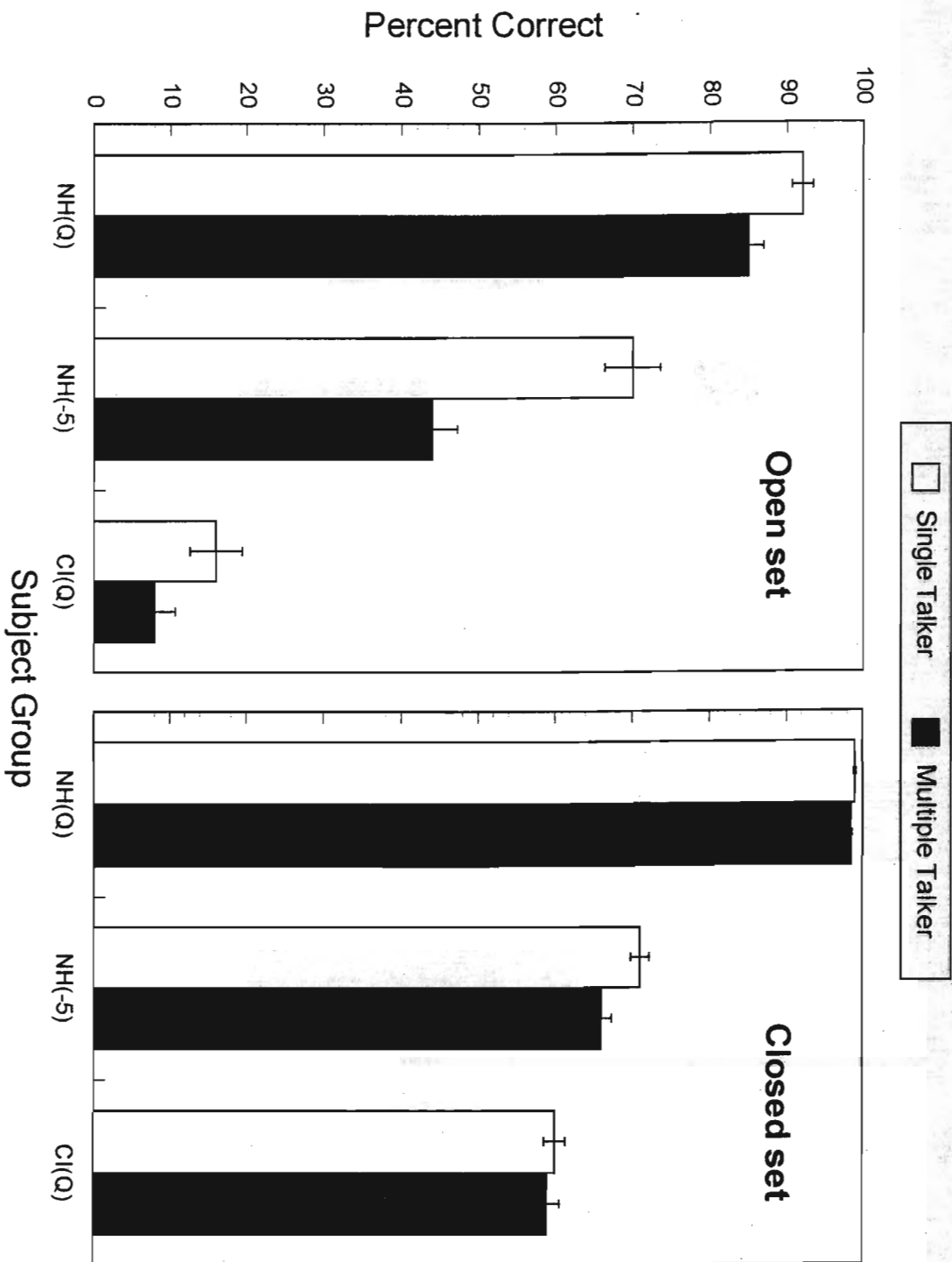
## RESULTS

Figure 1 shows percent correct identification for single- and multiple-talker word lists. The left side of the figure shows identification performance using an open-set response format and the right side of the figure displays scores obtained using a closed-set response format. The three subjects groups tested were: (1) NH(Q)-normal-hearing listeners tested in quiet; (2) NH(-5)-normal-hearing listeners tested at a -5 signal-to-noise ratio and; (3) CI(Q) cochlear implant patients tested in quiet. The differences between single- and multiple-talker lists were significant for all three subject groups tested in the open-set format. None of the differences for the closed-set response format reached statistical significance.

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Insert Figure 1 about here  
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Figure 2 shows a comparison of identification scores for easy and hard words presented in single-talker contexts. Data for the open- and closed-set response formats are shown in the left and right graphs, respectively. Subject group labels are identical to those of figure 1. For the open-set response format, all three groups demonstrated better identification performance for lexically easy, compared to lexically hard words. With a closed-set response format, normal-hearing listeners failed to demonstrate an effect of lexical

# Single vs. multiple talkers



**Figure 1.** Percent correct identification for single- and multiple-talker word lists. The left graph shows identification performance using an open-set response format and the right graph displays scores obtained using a closed-set response format. The three subject groups tested were: (1) NH(Q)-normal-hearing listeners tested in quiet; (2) NH(-5/n)-normal-hearing listeners tested at a -5 signal-to-noise ratio and; (3) CI(Q) cochlear implant patients tested in quiet. The differences between single- and multiple-talker lists were significant for all four groups tested in the open-set format. None of the differences for the closed-set response format reached statistical significance.

difficulty while cochlear implant patients continued to show better identification performance for lexically-easy words.

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Insert Figure 2 about here  
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Figure 3 shows a comparison of identification scores for easy and hard words presented in the multiple-talker contexts. Subject groups are the same as in figure 1. Both normal-hearing and cochlear-implant subjects demonstrated better identification scores for easy words in the open-set format. None of the differences between easy and hard words using the closed-set format reached statistical significance.

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Insert Figure 3 about here  
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## CONCLUSIONS

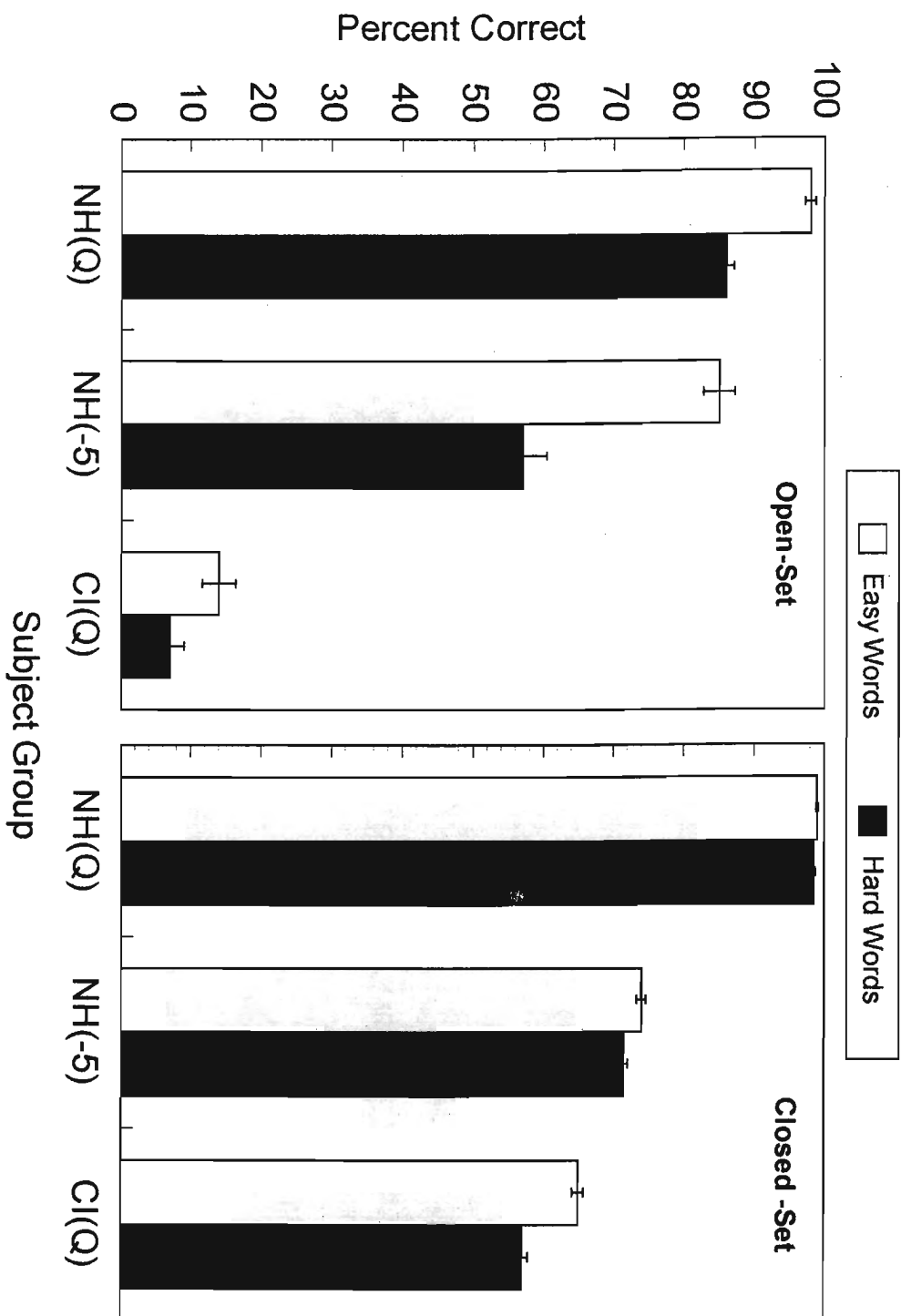
The results of the present experiments have several important implications for assessing the speech perception abilities of both impaired- and normal-hearing subject populations: First, the findings extend previous research on stimulus variability and spoken word recognition (Sommers, Nygaard & Pisoni, 1994) by demonstrating that both cochlear-implant patients and normal-hearing listeners exhibit poorer open-set word identification scores for multiple-, compared to single-talker contexts. Standard clinical assessments of speech perception generally do not include conditions in which test items are produced by several different talkers. Such testing protocols, therefore, may not provide sufficiently robust evaluations of the perceptual capacities required to perceive speech under natural listening conditions which typically include productions by several different talkers.

Furthermore, the best performing cochlear implant patients often approach ceiling-level performance on standardized speech perception tests. Development of assessment instruments that include multiple-talker contexts would provide a means of reducing overall performance levels and allow researchers to document performance gains for the best-performing CI patients over longer periods of time.

Secondly, the lexical difficulty of test items affects perceptual identification performance for both cochlear implant patients and normal-hearing listeners. In single-talker contexts, both subject populations demonstrated better open-set identification for lexically-easy words than for lexically-hard items. This finding suggests that *overall* performance measures for different speech perception tests may be substantially influenced by the proportion of easy and hard words they contain. As the concept of lexical difficulty is a relatively recent development in models of spoken language processing, none of the standard speech perception tests has controlled for this factor. Therefore, it may not be possible to make valid comparisons of overall performance measures across different assessment instruments.

Third, the effects of stimulus variability and lexical difficulty on spoken-language processing are reduced when listeners are tested using closed-set response formats. This finding suggests a fundamental difference in the perceptual mechanisms that are engaged with open- and closed-set response formats. If the goal of assessment protocols for CI patients is to measure speech perception abilities under conditions simulating natural listening environments, then instruments employing open-set formats and multiple-talker contexts will provide more valid measures of such capabilities.

## Easy vs. hard words (single talker)



**Figure 2.** Comparison of identification scores for easy and hard words presented in single-talker contexts. Data for the open- and closed-set response formats are shown in the left and right graphs, respectively. Subject group labels are identical to those of Figure 1. For the open-set response format, all three groups demonstrated significantly better identification performance for the easy, compared to the hard words. With a closed-set response format, however, differences between easy and hard words for normal-hearing listeners (both in quiet and at a -5 signal-to-noise ratio) were not significant. Cochlear implant patients, in contrast, had higher identification scores for easy words in both the open- and closed-set formats.

# Easy vs. hard words (multiple talkers)

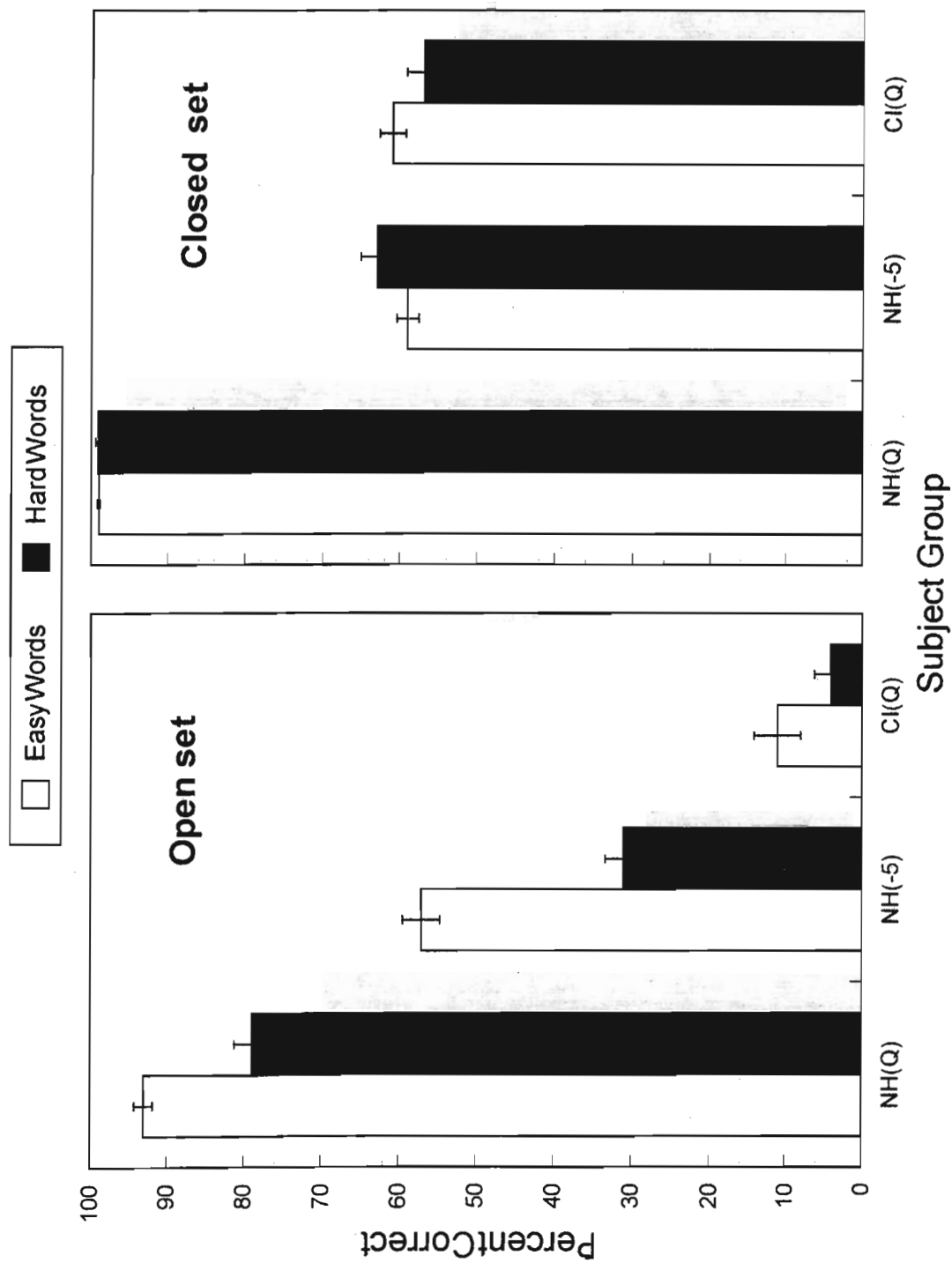


Figure 3. Comparison of identification scores for easy and hard words produced in multiple-talker contexts. Normal-hearing subjects and cochlear implant patients both demonstrated reduced identification performance for lexically hard words in the open-set format. None of the differences between easy and hard words using the closed-set format reached statistical significance.

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