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**Auditory Word Recognition by Pediatric Cochlear Implant Users:
Lexical and Indexical Influences¹**

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Abstract

Two experiments were conducted to examine the influence of lexical difficulty and stimulus variability on speech perception by children who use either a cochlear implant or a hearing aid. The effects of lexical factors were examined by comparing the recognition of lexically "easy" and "hard" words, as defined by the Neighborhood Activation Model³ using a monosyllabic word test and a multisyllabic word test. The recognition of "easy" and "hard" monosyllabic words was compared to word recognition on a traditional clinical monosyllabic test, the PB-K. Stimulus variability was examined by comparing word recognition in single-talker and multiple-talker conditions. The results of these experiments demonstrated that these subjects' spoken word recognition was better for lexically "easy" multisyllabic words than for "hard" multisyllabic words. Lexical difficulty did not seem to influence the recognition of monosyllabic words. Scores for the new tests were higher than for the PB-K, suggesting that the PB-K underestimates the speech perception skills of listeners with profound hearing impairment. Finally, introducing stimulus variability by varying the talker across trials did not affect spoken word recognition.

Auditory Word Recognition By Pediatric Cochlear Implant Users: Lexical And Indexical Influences

Introduction

Recent findings by Pisoni and his colleagues^{4,5,7} have demonstrated that spoken word recognition by adults and children with normal hearing is influenced by the lexical and indexical characteristics of the stimulus items. Lexical characteristics include the frequency of occurrence of the stimulus words, and the neighborhood density (i.e. the number of words that can be created from a stimulus word by adding, deleting, or substituting a single phoneme). Words that have a high frequency of occurrence and a low neighborhood density ("easy" words) are identified more accurately than words with the opposite lexical characteristics ("hard" words)³. Indexical properties, such as talker or speaking rate, also influence word identification. Listeners with normal hearing show about a 10% decrease in word identification when talker or speaking rate varies across trials^{5,7}, compared to conditions with no variability across these dimensions.

Purpose

The purpose of the present investigation was:

- 1) to examine subjects' performance on new assessment instruments designed to measure the use of lexical and indexical speech characteristics
- 2) to compare the performance on these new tests with performance on a clinically-used measure of word recognition (PB-K)
- 3) to compare the performance of children with multichannel cochlear implants to that of children with hearing aids

Experiment I examined multichannel cochlear implant and hearing aid users' recognition of open-set word lists constructed on the basis of word frequency and lexical density. Children's performance on these measures was compared to that on the PB-K. Experiment II examined the effect of children's recognition of words produced by a single talker or by multiple talkers.

Experiment I: Lexical Effects

Subjects

All cochlear implant subjects met the criteria for implantation including profound hearing impairment, and the inability to benefit from conventional amplification. The hearing aid subjects were considered borderline candidates for a cochlear implant. Subject characteristics are presented in Table 1.

Insert Table 1 about here

Table 1.
Subject characteristics for Experiment I.

	Monosyllabic Tests		Multisyllabic Tests	
	CI (N=15)	HA (N=3)	CI (N=5)	HA (N=1)
Mean Unaided Pure Tone Average	>110 dB HL	<u>Right ear:</u> 107 dB HL <u>Left ear:</u> 105 dB HL	> 110 dB HL	<u>Right ear:</u> 108 dB HL <u>Left ear:</u> 106 dB HL
Mean length of device use	3.2 years	8.8 years	3.6 years	10.5 years
Mean years deaf	6.1 years	1.0 years	6.3 years	0.3 years
Mean age at onset	0.3 years	0.0 years	0.5 years	0.0 years
Mean age fit	6.4 years	1.0 years	6.3 years	0.3 years

PROCEDURES

Two new tests, the Lexical Neighborhood Test (LNT) and the Multisyllabic Lexical Neighborhood Test (MLNT) of word recognition were developed using vocabulary drawn from a corpus of words obtained from research on child language development (CHILD Language Database Exchange System)². Test words were drawn from a subset of words produced by 3-5 year old children with normal hearing. Each test contains one easy and one hard list. These lists were generated based on an analyses of the frequency of occurrence and lexical density of words in the database². The PB-K test was also administered to provide baseline data to compare performance on the two new measures. All tests were administered live voice.

RESULTS

Monosyllabic Word Identification

Figure 1 reveals that the two groups obtained similar scores on the PB-K. However, scores on the LNT were higher for the cochlear implant subjects than for the hearing aid subjects. These data suggest that the PB-K does not differentiate between performance as a function of sensory aid, and that subjects receive more benefit from multichannel cochlear implants than from conventional hearing aids. Figure 1 also shows that performance was similar on both the easy and hard lists of the LNT. It is not clear whether these children have perceptual spaces that differ from those of persons with normal hearing, or whether monosyllabic word identification is so difficult that the lexical effects are not evident.

Insert Figure 1 about here

Figure 2 presents a closer examination of the relationship between performance on the PB-K and the LNT. Performance on the PB-K is moderately related to performance on both lists of the LNT. It appears that the PB-K may underestimate the performance of these subjects as the LNT yielded a greater range of scores than did the PB-K. That is, the LNT may reveal the word recognition abilities in children that are not evident on traditional clinical tests. Finally, there is a strong relationship between performance on the easy and hard lists of the LNT.

Multisyllabic Word Identification

A comparison of Figures 2 and 3 demonstrates that performance was better on the multisyllabic than on the monosyllabic word lists. This finding is common in persons with normal hearing and reflects the linguistic redundancy and lack of easily confusable words among the items of the MLNT.

Insert Figure 2 about here

Insert Figure 3 about here

MONOSYLLABIC WORD IDENTIFICATION

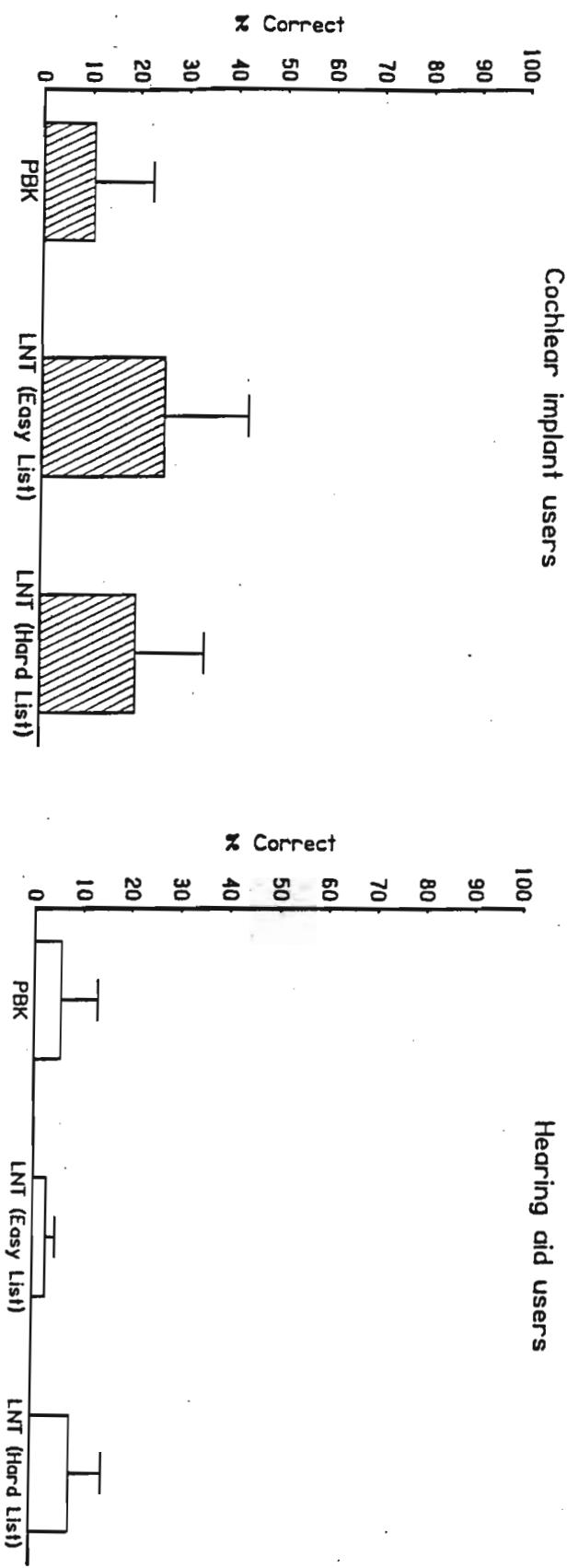


Figure 1. The percentage of words correctly identified on the PBK and on the two lexical conditions of the LNT by cochlear implant subjects (N=15) and hearing aid subjects (N=3).

MONOSYLLABIC WORD IDENTIFICATION

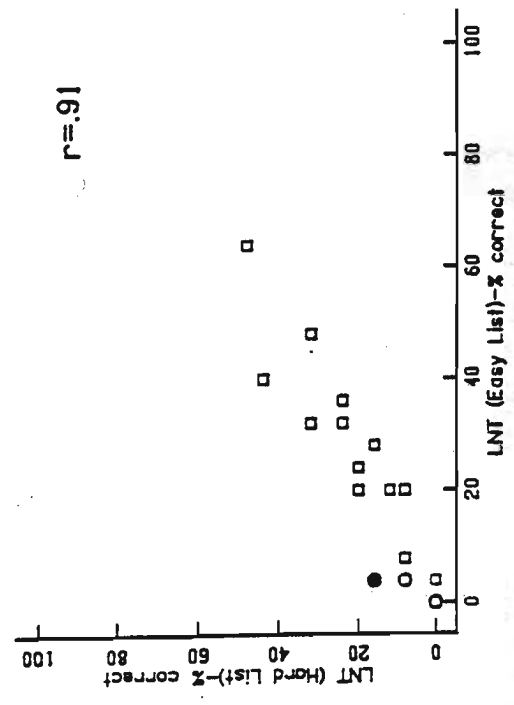
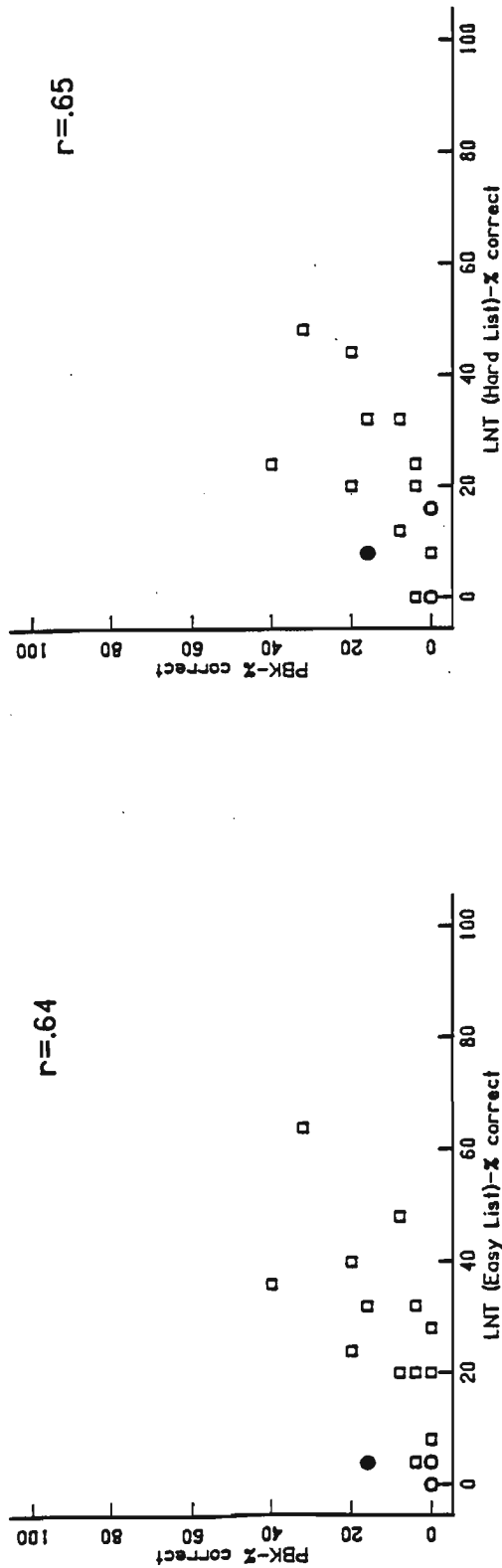


Figure 2. The relationship between performance on the PBK and the LNT, and between the two lexical conditions on the LNT.

MULTISYLLABIC WORD IDENTIFICATION

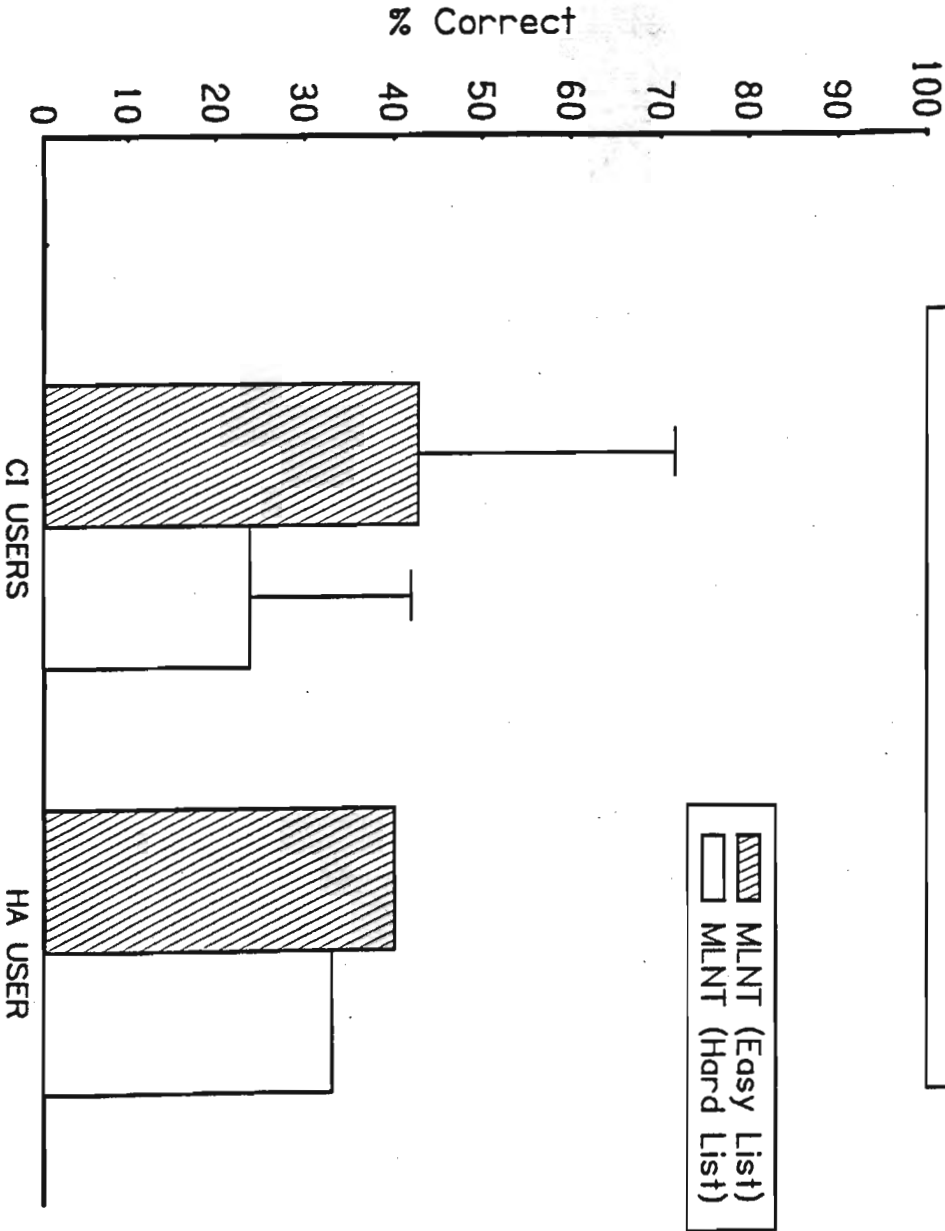


Figure 3. The percentage of multisyllabic words correctly identified in the two lexical conditions by cochlear implant users (N=1) and hearing aid user (N=1).

The data in Figure 3 illustrate that word identification was better in the "easy" than in the "hard" condition for these MLNT items. This suggests that these children do exhibit some of the same perceptual confusions demonstrated by earlier investigations into the performance of listeners with normal hearing. These results also suggest that the failure to find lexical effects with monosyllabic words is likely due to the extreme difficulty these children have in encoding these speech signals.

Experiment II: Sources of Variability

Subjects

Ten multichannel cochlear implant and two hearing aid users who were borderline candidates for a cochlear implant served as subjects. Information about the subjects is presented in Table 2.

Insert Table 2 about here

Procedures

Table 3 presents a description of the stimulus materials employed in this experiment. All stimulus items were recorded at a conversational speaking rate. Subjects were given a different word list in each condition, and presentation order was counterbalanced across subjects.

Insert Table 3 about here

Results

Figure 4 illustrates that no talker effect was evident for either subject group. That is, performance on single- and multiple-talker contexts did not differ. There are several possible reasons for this finding. First, perhaps these subjects may not receive enough information from their multichannel cochlear implants to detect a difference among the talkers. This seems unlikely as adult cochlear implant users can detect the difference between male and female talkers with great accuracy¹. Secondly, talker effects and other sources of variability are obscured when a closed-set format is employed⁷. Finally, there may be floor effects due to the use of recorded stimulus materials that are produced at a conversational rate.

Insert Figure 4 about here

Table 2.
Subject characteristics for Experiment II

	WIPI Test	
	CI (N=10)	HA (N=2)
Mean Unaided Pure Tone Average	>110 dB HL	<u>Right ear:</u> 106 dB HL <u>Left Ear:</u> 105 dB HL
Mean length of device use	3.7 years	10.5 years
Mean years deaf	6.6 years	1.4 years
Mean age at onset	0.3 years	0.0 years
Mean age fit	6.9 years	1.4 years

Table 3.

A description of the stimuli used in Experiment II.

TEST	CONDITIONS	STIMULI	RESPONSE MODE	SCORING
<u>Adaptation of the Word Identifi- cation by Picture Index</u>	Single talker: Items produced by a male talker Multiple talkers: Items produced by 5 male and 5 female talkers	25 mono- syllabic words 25 mono- syllabic words	Closed-set (6 choices per item)	% of words correctly identified

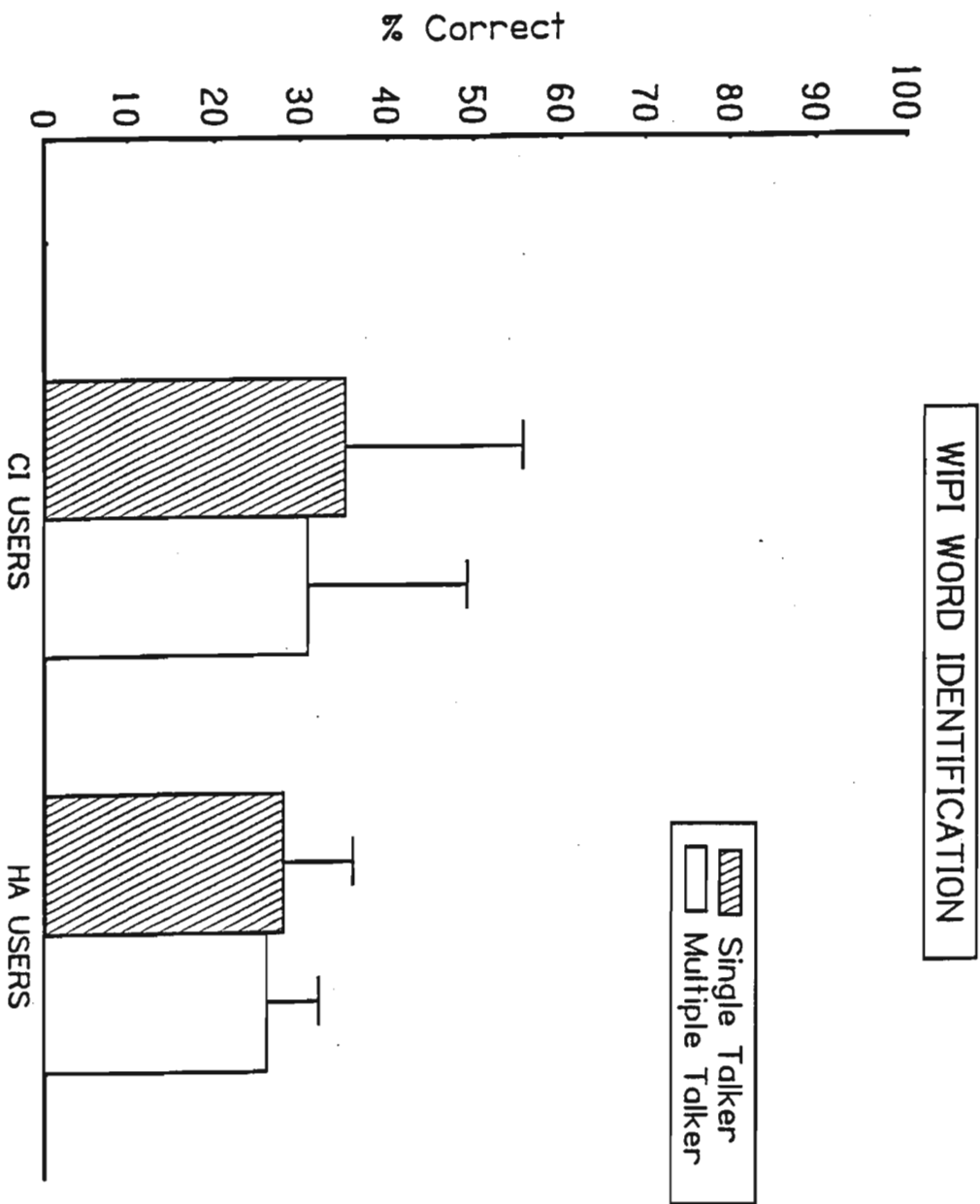


Figure 4. The percentage of words correctly identified in the two talker conditions by multichannel cochlear implant users (N=10) and hearing aid users (N=2).

Conclusions

Experiment I

The results of Experiment I demonstrated that spoken word recognition by children who use cochlear implants or hearing aids is influenced by the lexical difficulty of the stimulus items. The data suggest that these subjects recognize spoken words in the context of other similar words in the lexicon, rather than as individual unrelated patterns. Thus, although the accuracy of their word recognition may be reduced, these subjects display lexical representations that are similar to those found in previous investigations with listeners with normal hearing.

The data also suggest that traditional speech perception tests such as the PB-K may underestimate the speech understanding of listeners with profound hearing loss. It may be that these traditional tests contain a high percentage of lexically difficult stimulus items that result in a reduced recognition score. An analysis of the lexical characteristics of the word recognition tests traditionally used with cochlear implant users is currently underway.

Experiment II

Word recognition performance was similar in the single- and multiple-talker conditions. Thus, introducing stimulus variability by varying the talker across trials did not affect word recognition. In order to examine these effects, it is necessary to develop procedures that yield scores above the floor of the test in the single-talker condition. However, the closed-set response format used in Experiment II to accommodate subjects with reduced word recognition skills may have obscured the effects of stimulus variability⁸. Future investigations will use an open-set response mode and present stimulus items that are distinctly articulated, as Picheny, Braida, & Durlach⁶ have shown that the use of "clear speech" increases speech understanding by listeners with hearing impairments.

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